ENVIRONMENTAL PROTECTION AGENCY
TECHNICAL ENFORCEMENT SUPPORT
AT
HAZARDOUS WASTE SITES

TES IV
CONTRACT NO. 68-01-7351
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TECHNICAL REVIEW
OF DOCUMENTS
FOR THE SAUGET SITES

EPA REGION V

JACOBS ENGINEERING GROUP INC.
PROJECT NO. 05-B489-00

PREPARED BY ICAIR LIFE SYSTEMS

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1.0   INTRODUCTION

1.1   Purpose

The purpose of this report is to provide a detailed review and summary of the
hydrogeology and groundwater pollution studies in the Sauget, Illinois area
previously described in four groundwater monitoring and source material data
reports:

1.   Assessment of Groundwater Conditions at the Village of Sauget
      Treatment Plant Sites (Geraghty & Miller, Inc. 1986a)

2.   Plant-wide Assessment of Groundwater Conditions at the W. G.
      Krummrich Plant, Monsanto Company (3 Volumes) (Geraghty & Miller,
      Inc. 1986b)

3.   Illinois EPA Comments on the Monsanto W. G. Krummrich Plant and
      Sauget Treatment Plant Sites. (Harza Environmental Services 1987)

4.   Remedial Investigation: Dead Creek Project Sites at Cahokia/Sauget,
      Illinois. Final Report (Ecology and Environment, Inc. March, 1988)

This report will summarize the hydrogeology and groundwater pollution studies
cited above, evaluate conclusions and recommendations, identify any data gaps,
and recommend future data acquisitions.

1.2   Site Background Information

The site is located in and around the cities of Cahokia and Sauget, Illinois,
south of East St. Louis and on the east bank of the Mississippi River. The
site occupies an area of about two square miles along the flood plain
(American Bottoms) and consists of 12 targeted, potential pollutant source
areas and six segments of Dead Creek. Areas range in size from about one acre
to one-half square mile. The site consists of a number of former municipal
and industrial waste landfills, surface impoundments or lagoons, surface
disposal areas and past excavations thought to be filled or partially filled
with unknown wastes. The American Bottoms aquifers have provided large
quantities of groundwater for more than 60 years. Prior to the development of
the East St. Louis area, the water table was very near the surface, and there
were many shallow lakes, ponds, swamps and marshes. The abundance of
groundwater and the site's proximity to railroads and the Mississippi River
favored industrial development of the area. Prior to the 1950s steel
manufacturing, oil refining, chemical manufacturing and meat packing were all
established; increased drainage efficiency lowered groundwater levels 2 to
12 feet leading to development of the present infrastructure. Since 1962,
fluctuating water levels caused by variations in precipitation, river stage
and degradation of groundwater quality have resulted in a gradual decrease in
groundwater usage and consequently a rise in groundwater levels. The high
water table has resulted in sewer line breaks, damaged foundations and increased
infiltration from landfills (Voelker 1984).

LIST OF FIGURES

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1 MILE

FIGURE 1-1 LOCATION MAP OF THE SAUCET AREA, ILLINOIS

- Site O contains four inactive sludge dewatering lagoons on the SSDRA property. The property covers approximately 45 acres, but the sludge lagoons occupy about 20 acres. The lagoons were used from 1967 to 1978 and have since been covered with a clay cap and vegetated. Chemical analyses of soil borings suggest that the lagoons and a pit located near the northeast corner of the lagoons may be contaminant source areas. A large amount of 'waste' was reportedly disposed of in the pit.

- Site Q is an inactive waste disposal facility covering approximately 90 acres on the east bank of the Mississippi River. It was operated from 1962 to 1975. Presently, the property is occupied by the Pillsbury Company. Large mounds of coal, cinders and household-type waste are present on the site.

- Site R is known as the Monsanto Krummrich Landfill and the Sauget Toxic Dump. It is an inactive industrial waste landfill (36 acres) owned by the Monsanto Chemical Company, and it was used between 1957 and 1977. Although it is currently clay capped and vegetated, it is suspected of being one of the major sources of groundwater pollution in the study area.

- Other property owned by Monsanto, identified as the Route 3 Drum Site, is not given a site designation in the Ecology and Environment (1988) report, but was examined in the Geraghty & Miller (1986b) study. It is estimated that 5,000 drums containing organic chemicals were deposited during the middle 1940s in this area in the southwest corner of the Monsanto property (see Figure 1-1).

- Site J is on the Sterling Steel Foundry property. It consists of two pits and a disposal area. The surface disposal area was used in 1955, occupies approximately five acres and contains casting sand, slag and miscellaneous debris.

- Site K is a former sand pit identified through historical aerial photographs. The pit has been filled with unknown material and covered with sand and gravel. The site was in operation from 1950 to 1973 and is presently operated by the Bank of Belleville.

- Site M is a former sand pit excavated by the H. H. Hall Construction Company in the mid- to late-1940s. The pit is approximately 275 feet by 350 feet, has an estimated depth of 40 feet and is presently filled with water. There is no evidence of waste disposal in the pit.

- Site N is an excavated area in the southwest corner of an inactive construction yard owned by the H. H. Hall Construction Company. The site occupies four acres and was partially filled with construction and demolition debris during the 1950s and early 1960s.

analyzed for all USEPA Priority Pollutants and some non-priority pollutants including volatile organic compounds, acid extractable organic compounds, base/neutral extractable organic compounds, total organic halogens (TOX), total organic carbon (TOC), chloride, total dissolved solids (TDS), temperature, pH and specific conductance. A single round of groundwater samples was collected in March, 1987 and July, 1987 from all 35 (shallow) monitoring wells in the Ecology and Environment (1988) study. Some of these wells were the same as those sampled during the Geraghty & Miller (1986a,b) studies. In addition to the monitoring wells, four residential wells and one active industrial well (Clayton Chemical Company) were sampled by Ecology and Environment personnel. All groundwater samples were submitted to the Analytical Services Center for analysis of organics on the Hazardous Substance List as well as metals and cyanides. Temperature, pH and specific conductivity measurements also were recorded in the field for each sample. At least one priority pollutant was detected in every well. Maximum and mean concentrations for each chemical are given in Tables 1-1 through 1-6. Too many changes in river stage, precipitation, groundwater level, sampling protocol and investigation personnel occurred over the investigation period to ascertain any time trend in contaminant concentrations and amounts of pollutants released to the aquifer.

1.4.2   Identification of Chemical Pollutants

Tables 1-1 through 1-6 present the maximum and mean concentrations measured for each chemical species. Data are presented for all wells, and for wells screened in the water table aquifer, intermediate aquifer, deep aquifer and bedrock aquifer. Each of the six tables summarizes the data for a specific category of chemical compounds: Table 1-1 lists volatile organic compounds, Table 1-2 lists acid extractable compounds, Table 1-3 lists base/neutral extractable compounds, Table 1-4 summarizes the data for pesticide/poly-chlorinated biphenyl (PCB) compounds, Table 1-5 provides the data for metals and Table 1-6 lists miscellaneous parameters. The data permit many observations to be made. Generally, more contaminants are found in the shallow wells than deep wells with all wells showing some degree of contamination. This includes wells in the bedrock indicating that vertical migration of the contaminants has occurred. Second, most of the priority pollutants are found somewhere in the groundwater in the sampling area. Thirty-five different priority pollutants have an average concentration greater than 1,000 ppb in at least one well and 22 of those exceed 10,000 ppb. Third, shallow wells typically exhibit higher contaminant concentrations than deeper wells, although some chemicals are found in higher concentrations at depth. This indicates that one or more of the following has occurred: vertical migration during leaching, sinking during horizontal transport or vertical transport along the casing of the deep wells.

1.5   Selected Pollutants of Concern

No formal criteria were used to select pollutants of concern. Instead, the available monitoring data were examined and ten contaminants were selected, which are found in reasonably high concentrations, are the most toxic, represent different organic fractions and exhibit a wide range of physical and chemical properties (Table 1-7). These contaminants are benzene,

TABLE 1-1   SUMMARY OF VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER

Volatile Organic Compounds	Concentration, ug/L									
	All Wells		Shallow Wells		Intermed. Wells		Deep Wells		Bedrock Wells	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
USEPA Priority Pollutant:										
Acrolein	0	0	0	0	0	0	0	0	0	0
Acrylonitrile	176	0.367	0	0	176	1.22	0	0	0	0
Benzene	596,000	4,381	596,000	5,397.8	69,200	1,805.50	4,940	385.25	23	7.67
bis-Chloromethyl ether	0	0	0	0	0	0	0	0	0	0
Bromoform	0	0	0	0	0	0	0	0	0	0
Carbon tetrachloride	2,340	2.83	0	0	2,340	13.45	0	0	0	0
Chlorobenzene	180,000	4,408.7	180,000	5,642.6	17,600	1,674.08	13,900	2,249.72	14,400	4,824.71
Chlorodibromomethane	0	0	0	0	0	0	0	0	0	0
Chloroethane	437	2.14	309	1.36	437	6.11	20.6	0.515	0	0
2-Chloroethylvinyl ether	23	0.028	0	0	23	0.13	0	0	0	0
Chloroform	3,000	51.0	3,000	83.17	64	4.34	12.9	0.523	0.8	0.27
Dichlorobromomethane	0	0	0	0	0	0	0	0	0	0
Dichlorodifluoromethane	0	0	0	0	0	0	0	0	0	0
1,1-Dichloroethane	3,560	26.56	3,560	39.23	224	13.24	0	0	0	0
1,2-Dichloroethane	18,500	201	18,500	288.33	3,510	132.66	0	0	0	0
1,1-Dichloroethylene	392	2.768	392	6.09	24	0.62	2	0.13	0	0
1,2-Dichloropropane	32.9	0.112	32.9	0.19	0	0	0	0	0	0
cis-1,3-Dichloropropylene	0	0	0	0	0	0	0	0	0	0
trans-1,3-Dichloropropylene	0	0	0	0	0	0	0	0	0	0
Ethylbenzene	25,000	175	25,000	284.61	359	18.70	40	2.60	0	0
Methyl bromide	8	0	0	0	0	0	0	0	0	0
Methyl chloride	138,000	484	30	0.48	138,000	1,583.51	0	0	0	0
Methylene chloride	127,000	752	52,000	692.66	127,000	1,271.13	7,140	250.06	400	134
1,1,2,2-Tetrachloroethane	12,000	44	12,000	71.83	42	4.45	0	0	0	0
Tetrachloroethylene	65	0.488	19	0.30	65	1.15	4.2	0.11	0	0
Toluene	18,500	252	15,000	393.35	18,500	28.02	194	14.57	1,180	406.89
trans-1,2-Dichloroethylene	19,300	208	19,300	349.92	19,200	199.28	2.7	0.13	0	0
1,1,1-Trichloroethane	7,800	48	7,800	78.48	0	0	66	4.77	0	0
1,1,2-Trichloroethane	76	0.200	8	0.02	76	0.89	0	0	0	0
Trichloroethylene	4,840	27	4,840	63.17	36	2.16	0	0	0	0
Trichlorofluoromethane	0	0	0	0	0	0	0	0	0	0
Vinyl chloride	7,340	28	7,340	41.59	258	13.82	51.3	7.82	0	0
Miscellaneous:										
Methyl-iso-butyl ketone	40,000	204	16,900	476.78	40,400	94.09	0	0	0	0
Methyl isoamyl ketone	5,130	31	5,130	84.00	0	0	19	0.63	0	0
Xylenes	86,700	467	86,700	786.71	1,630	63.54	149.8	13.38	0	0

TABLE 1-2 SUMMARY OF ACID EXTRACTABLE COMPOUNDS IN GROUNDWATER

Acid Extractable Organic Compounds	Concentration, ug/L									
	All Wells		Shallow Wells		Intermed. Wells		Deep Wells		Bedrock Wells	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
USEPA Priority Pollutant:										
2-Chlorophenol	718,000	5,919.4	718,000	8,725.22	116,000	2,989.9	237	26.0	5,630	1,888.7
2,4-Dichlorophenol	1,520,000	5,518.3	1,520,000	7,628.97	97,400	3,373.1	818	33.4	31,200	10,431.4
2,4-Dimethylphenol	44,500	371.6	44,500	389.10	38,300	685.2	186	11.2	4.8	1.0
4,6-Dinitro-o-cresol	0	0	0	0	0	0	0	0	0	0
2,4-Dinitrophenol	1,300	3.5	1,300	5.72	0	0	0	0	0	0
2-Nitrophenol	729	4.4	729	7.06	0	0	55	2.2	3	0.33
4-Nitrophenol	7,590	33.4	276	5.20	7,590	149.5	372	10.1	0	0
p-Chloro-m-cresol	7	0.03	7	0.06	0	0	0	0	0	0
Pentachlorophenol	35,000	377.2	35,000	566.40	3,690	67.9	63	4.2	1,360	453.3
Phenol	1,070,000	14,535.1	965,000	19,121.14	1,070,000	14,957.3	234	21.3	14,600	4,915.7
2,4,6-Trichlorophenol	31,200	653.7	21,900	675.85	31,200	687.8	149	5.5	65.2	17.2
Miscellaneous:										
4-Chlorophenol	299,000	5,292.6	299,000	13,092.81	49,900	1,843.6	1,920	176.0	37.1	8.2

TABLE 1-3 SUMMARY OF BASE/NEUTRAL EXTRACTABLE COMPOUNDS IN GROUNDWATER

Base/Neutral Extractable Organic Compounds	Concentration, ug/L									
	All Wells		Shallow Wells		Intermed. Wells		Deep Wells		Bedrock Wells	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
USEPA Priority Pollutant:										
Acenaphthene	27.3	0.11	27.3	0.14	1.9	0.023	1	0.03	0	0
Acenapthylene	0	0	0	0	0	0	0	0	0	0
Anthracene	10.6	0.03	2	0.02	10.6	0.065	0	0	0	0
Benzidine	1940	10.44	1,940	24.87	1	0.019	0	0	0	0
Benzo(a)anthracene	32	0.24	32	0.39	0	0	0	0	0	0
Benzo(a)pyrene	0	0	0	0	0	0	0	0	0	0
Benzo(b)fluoroanthene	0	0	0	0	0	0	0	0	0	0
Benzo(ghi)perylene	0	0	0	0	0	0	0	0	0	0
Benzo(k)fluoranthene	0	0	0	0	0	0	0	0	0	0
bis(2-Choroethoxy) methane	7,300	56.99	7,300	94.52	0	0	0	0	0	0
bis(2-Chloroethyl) ether	91	0.33	91	0.55	0	0	0	0	0	0
bis(2-Chloroisopropyl) ether	3	0.02	3	0.04	0	0	0	0	0	0
bis(2-Ethylhexyl)phthalate	779	11.12	434	7.87	779	18.969	84	5.68	109	36.3
4-Bromophenyl phenyl ether	0	0	0	0	0	0	0	0	0	0
butyl benzyl phthalate	14	0.08	14	0.11	8	0.074	0	0	0	0
2-Chloronaphthalene	0	0	0	0	0	0	0	0	0	0
4-Chlorophenyl phenyl ether	28	0.21	28	0.34	0	0	0	0	0	0
Chrysene	6	0.04	6	0.07	0	0	0	0	0	0
Dibenzo(a,h)anthracene	0	0	0	0	0	0	0	0	0	0
1,2-Dichlorobenzene	13,500	196.62	11,000	229.20	13,500	170.27	3,270	207.10	4.9	1.1
1,3-Dichlorobenzene	28,500	218.49	320	8.29	156	2.26	776	40.42	28,500	9,500
1,4-Dichlorobenzene	15,000	181.73	15,000	254.67	1,220	43.88	1,030	113.72	0	0
3,3-Dichlorobenzidine	0	0	0	0	0	0	0	0	0	0
Diethyl phthalate	140	1.57	140	2.59	2	0.037	0	0	0	0
Dimethyl phthalate	98	1.07	98	1.30	0	0	0	0	0	0
di-n-butyl phthalate	304	2.41	127	2.63	304	3.511	8	0.53	1	0.3
2,4-Dinitrotoluene	65,700	483.44	3	0.03	91	1.69	0	0	65,700	21,900
2,6-Dinitrotoluene	0	0	0	0	0	0	0	0	0	0
di-n-octyl phthalate	40	0.50	40	0.83	0	0	0	0	0	0
1,2-Diphenylhydrazine	0	0	0	0	0	0	0	0	0	0
Fluoranthene	0	0	0	0	.0	0	0	0	0	0
Fluorene	25	0.18	25	0.30	0	0	0	0	0	0
Hexachlorobenzene	6	0.04	6	0.07	0	0	0	0	0	0
Hexachlorobutadiene	0	0	0	0	0	0	0	0	0	0
Hexachlorocyclopentadiene	0	0	0	0	0	0	0	0	0	0
Hexachloroethane	850	2.08	850	3.46	0	0	0	0	0	0
Indeno(1,2,3-c,d)pyrene	11	0.03	11	0.04	0	0	0	0	0	0

Table 1-3 - continued

Base/Neutral Extractable Organic Compounds	Concentration, ug/L									
	All Wells		Shallow Wells		Intermed. Wells		Deep Wells		Bedrock Wells	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Isophorone	110	1.18	110	1.63	76.6	0.975	0	0	0	0
Naphthalene	21,000	177.82	21,000	265.84	11,600	87.87	4.1	0.225	0	0
Nitrobenzene	8,080	77.33	8,080	95.72	4,030	98.56	0	0	8.2	2.2
n-Nitrosodimethylamine	800	5.88	800	9.76	0	0	0	0	0	0
n-Nitrosodi-n-propylamine	6	0.05	0	0	4.9	0.045	72.4	3.62	0	0
n-Nitrosodiphenylamine	72.4	0.72	18	0.17	25	0.747	0	0	0	0
Phenanthrene	15	0.11	15	0.19	0	0	0	0	0	0
Pyrene	15.8	0.06	15.8	0.10	0	0	20.3	2.16	0	0
1,2,4-Trichlorobenzene	2,700	53.52	2,700	86.13	520	5.44	0	0	0	0
2-Nitroaniline	3,280	59.78	2,000	59.61	3,280	122.34	0	0	706	185.8
4-Nitroaniline	1,780	24.97	346	4.77	1,780	84.00	1,954	97.7	0	0
Nitrochlorobenzenes	476,000	15,467.19	476,000	39,409.69	124,000	3,827.18	0	0	0	0
2,4- and 3,4-Dinitrochlorobenzene	222	0.68	222	1.85	0	0	0	0	0	0
4-Nitrodiphenylamine	949	20.68	682	31.23	949	29.98	-	-	-	-
Triphenyl phosphate	607	13.25	412	18.13	607	21.39	0	0	0	0
2,3,7,8-Tetrachloro-dibenzo-p-dioxin	0	0	0	0	0	0	0	0	0	0
2-Nitrobiphenyl	42.9	0.26	42.9	0.74	0	0	0	0	0	0
4-Nitrobiphenyl	0	0	0	0	0	0	0	0	0	0

TABLE 1-4   SUMMARY OF PESTICIDE AND PCB COMPOUNDS IN GROUNDWATER

1-12

Pesticide/PCB Compounds	All Wells		Shallow Wells		Intermed. Wells		Deep Wells		Bedrock Wells	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
USEPA Priority Pollutant:										
Aldrin	0.58	0.005	0.58	0.0053	0.139	0.008	0.034	0.003	0	0
Alpha-BHC	70	0.721	70	1.0865	17.5	0.311	0.046	0.002	0	0
Beta-BHC	6	0.024	0.108	0.0020	6	0.104	0	0	0	0
Gamma-BHC	42	0.227	0.73	0.0054	42	0.707	19.3	0.967	0	0
Delta-BHC	0.243	0.002	0.243	0.0016	0.068	0.003	0.014	0.001	0	0
Chlordane	0.469	0.003	0	0	0.469	0.016	0	0	0	0
4,4'-DDT	0	0.000	0	0	0	0	0	0	0	0
4,4'-DDE	0.004	0.000	0.004	0.0000	0	0	0	0	0	0
4,4'-DDD	0.148	0.002	0.063	0.0008	0.148	0.005	0	0	0	0
Dieldrin	0.052	0.000	0.002	0.0000	0.052	0.001	0	0	0	0
Endosulfan I	0.136	0.001	0	0	0	0	0	0	0	0
Endosulfan II	0	0.000	0	0	0	0	0	0	0	0
Endosulfan sulfate	4.35	0.019	0.167	0.0010	1.09	0.029	4.35	0.169	0	0
Endrin	283	1.572	0	0	283	7.029	15.2	0.76	0	0
Endrin aldehyde	0.258	0.001	0.258	0.0032	0.014	0.000	0.014	0.001	0	0
Heptachlor	68.2	0.261	68.2	0.4112	2.09	0.053	0.47	0.024	0	0
Heptachlor epoxide	1.01	0.004	1.01	0.0061	0.092	0.002	0	0	0	0
Aroclor-1016	0	0.000	0	0	0	0	0	0	0	0
Aroclor-1221	0	0.000	0	0	0	0	0	0	0	0
Aroclor-1232	0	0.000	0	0	0	0	0	0	0	0
Aroclor-1242	10.69	0.039	0	0	10.69	0.178	0	0	0	0
Aroclor-1248	0	0.000	0	0	0	0	0	0	0	0
Aroclor-1254	52	0.413	52	0.6866	0	0	0	0	0	0
Aroclor-1260	890	6.213	890	10.0856	74.8	0.676	0	0	0	0
Toxaphene	0	0.000	0	0	0	0	0	0	0	0

Concentration, ug/L

TABLE 1-5 SUMMARY OF METALS IN GROUNDWATER

| Metals | Concentration, ug/L, Except Where Noted | | | | | | | | | |
| | All Wells | | Shallow Wells | | Intermed. Wells | | Deep Wells | | Bedrock Wells | |
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Aluminum	11.8	0.1394	11.8	0.2605	0.15	0.0160	0.34	0.0253	0.078	0.0404
Antimony	2.6	0.0291	2.6	0.0460	0.14	0.0061	0.002	0.0001	0	0
Arsenic	14	0.2890	14	0.2890	-	-	-	-	-	-
Barium	2.045	0.0745	2.045	0.1584	0.192	0.0070	0	0	0	0
Beryllium	0.057	0.0016	0.057	0.0016	-	-	-	-	0	0
Boron	62.5	0.5086	0.07	0.0015	7.46	0.2813	4.82	0.2412	-	-
Cadmium	25.8	0.3747	25.8	0.6195	0.15	0.0078	0.046	0.0023	0	0
Chromium	0.758	0.0155	0.758	0.0155	-	0.0033	-	0.0005	0.013	0.0092
Cobalt	2.41	0.0344	2.41	0.0728	0.05	0.0025	0.01	0.0008	-	-
Copper	104	1.5311	104	2.6981	0.041	-	0.016	0.00002	0	0
Lead	8.02	0.2558	8.02	0.2558	-	0.0001	0.0004	0.0052	0.007	0.0029
Manganese	13.2	0.8994	13.2	2.0496	0.0064	0.0123	0.068	0.0044	0	0
Mercury	17.2	0.1322	17.2	0.2105	0.091	0.0024	0.133	0.0002	0.003	0.0013
Nickel	2.21	0.0257	2.21	0.0414	0.067	0.0027	0.003	0.0467	0.02	0.0158
Selenium	0.117	0.0025	0.117	0.0029	0.066	0.0478	0.533	-	-	-
Silver	0.533	0.0167	0.024	0.0005	0.41	-	-	-	-	-
Thallium	0.354	0.0120	0.354	0.0120	-	-	-	-	-	-
Tin	0	0.0000	0	0.0000	-	-	-	-	-	-
Vanadium	6.84	0.1095	6.84	0.1632	0.49	0.0576	0.16	0.0313	0.561	0.3421
Zinc	6.41	0.2718	6.41	0.2718						

TABLE 1-6 SUMMARY OF MISCELLANEOUS PARAMETERS IN GROUNDWATER

Miscellaneous Parameters In Groundwater	All Wells		Shallow Wells		Intermed. Wells		Deep Wells		Bedrock Wells	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
pH (units)	9	6.9	8.5	7.0	8.4	6.8	9	7.1	7.6	6.8
Spec. conductance (µmhos/cm)	30,000	1,921.7	30,000	2,337.7	8,000	1,652.5	6,300	2,184.4	1,620	1,362.5
Temperature (centigrade)	24	15.2	24	14.9	23.5	14.4	24	14.9	21	18.5
Total organic carbon	7,900	258.0	7,900	321.9	4,500	287.5	1,000	160.5	257	128.9
Total phenols	10,000	184.7	10,000	244.6	10,000	193.5	1,036	92.4	0.4	0.1
Total organic halogens	1,500	157.3	1,500	162.3	1,200	135.6	1,300	345.3	-	-
Total dissolved solids	10,422	1,530.5	10,422	1,980.1	4,704	1,259.5	3,384	1,722.5	1,276	1,076.0
Bicarbonate (as $CaCO_3$)	1,400	783.3	1,090	840.0	1,400	706.6	930	875.0	-	-
Calcium	265,000	26,232.3	524	294.0	265,000	52,247.7	228	213.0	-	-
Chloride	5,198	289.5	5,198	337.8	990	198.9	1,265	320.8	350	275.0
Cyanide	1.6	0.02	1.56	0.027	0.0	0.00	0	0.0	0.24	0.1
Iron	27,500	1,560.0	27,500	1,327.5	23,900	4,756.6	85.2	44.4	-	-
Magnesium	59,200	5,912.2	129	69.0	59,200	11,749.9	66.6	65.3	-	-
Potassium	20,000	2,103.9	174	92.7	20,000	4,018.5	406	209.0	-	-
Sodium	86,800	9,033.6	1,250	655.8	86,800	17,535.8	785	508.5	-	-
Sulfate (as SO_4)	930	392.7	930	468	770	448	700	358	-	-
Acetone	38,000	344.46	38,000	344.46						
Bromodichloromethane	1	0.02	1	0.02						
Bromomethane	0	0	0	0						
2-Butanone (MEK)	62,000	16.68	62,000	16.68						
Carbon disulfide	3	0.06	3	0.07						
Chloromethane	0	0	0	0						
cis-1,3-Dichloropropene	0	0	0	0						
Dibromochloromethane	0	0	0	0						
1,1-Dichloroethene	10	0.21	10	0.22						
2-Hexanone	5	0.10	5	0.11						
2-Methyl-2-pentanone	38,000	204.76	38,000	204.76						
Styrene	50	0.63	50	0.63						
Tetrachloroethene	1,000	18.89	1,000	18.89						
trans-1,2-Dichloroethene	14,000	31.35	14,000	31.36						
Trichloroethene	83,000	37.37	83,000	37.38						
Vinyl acetate	0	0	0	0						

Concentration, ug/L, Except Where Noted

Table 1-6 - continued

Miscellaneous Parameters In Groundwater	All Wells		Shallow Wells		Concentration, ug/L, Except Where Noted Intermed. Wells		Deep Wells		Bedrock Wells	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Benzoic acid	35,000	839.56	35,000	839.57						
Benzyl alcohol	8,600	204.56	8,600	204.57						
4-Chloroaniline	15,000	1,454.78	15,000	1,454.78						
4-Chloro-3-methylphenol	140	3.04	140	3.04						
Dibenzofuran	6	0.13	6	0.13						
4,6-Dinitro-2-methylphenol	0	0	0	0						
2-Methylnaphthalene	0	6.03	200	6.03						
2-Methylphenol	200	23.73	810	23.74						
4-Methylphenol	810	702.54	23,000	702.54						
3-Nitroaniline	23,000	61.52	3,900	61.52						
2,4,5-Trichlorophenol	3,900	13.19	580	13.20						
Methoxychlor	580	0	0	0						
Endrin ketone	0	0	0	0						

chlorobenzene, trichloroethylene, tetrachloroethylene, phenol, dichlorobenzene, bis(2-ethylhexyl)phthalate, polychlorinated biphenyls, benzene hexachloride and arsenic.

Benzene

Benzene is produced by petroleum refining, coal tar distillation, coal processing and coal coking (NAS 1977). Benzene is a purgeable organic on the EPA Priority Pollutant list. It is a suspected carcinogen, and its concentration in the monitoring wells often exceeds the Maximum Contaminant Level (MCL) of 5 ppb (Maximum Contaminant Level Goal (MCLG) of 0 ppm) (Table 1-1). An ambient water quality criteria level of 6.6×10^{-4} ppm has been established for carcinogenicity protection of human health from the ingestion of water and organisms. Benzene is moderately insoluble in water and is highly volatile (Table 1-7). It is lighter than water, and thus may be expected to be transported differently than surface water or groundwater and the other chemical contaminants. Its octanol water partition coefficient (K_{ow}) and organic carbon partition coefficient (K_{oc}) indicate that sorption processes are likely removal mechanisms from water, and that groundwater transport of benzene may be significantly retarded. Volatilization appears to be the major transport process of benzene from surface waters to ambient air. Direct oxidation of benzene in water is unlikely, but it is susceptible to photooxidation in air. The bioaccumulation potential of benzene is low (Frietag et al. 1985).

Chlorobenzene

Chlorobenzene is used in the manufacture of aniline, insecticides, phenol and chloronitrobenzene and as an intermediate in the manufacture of dyestuffs (NAS 1977). Chlorobenzene, a purgeable organic, is also a suspected carcinogen, has an MCLG of 0.06 ppm, has an ambient water quality criteria for toxicity protection of human health for ingestion of water and organisms of 0.488 ppm, is slightly less soluble and volatile than benzene, exhibits a similar tendency to photooxidize, and is found in very high concentrations at the site. Chlorobenzene has a modest bioaccumulation potential (Frietag, et al. 1985). Its K_{ow} and K_{oc} indicate a strong adsorption to soils, so that its transport in groundwater may be significantly retarded.

Trichloroethylene

Trichloroethylene is used primarily in metal degreasing. It is also used in dry-cleaning operations, in organic synthesis and in refrigerants and fumigants (NAS 1977). Trichloroethylene is also a purgeable organic and suspected carcinogen. It has an MCLG of 0 ppm, an MCL of 5 ppb and an ambient water quality criteria for carcinogenicity protection of human health of 2.7×10^{-3} ppm for the ingestion of water and organisms. It is moderately soluble in water, is highly volatile, photooxidizes in air rapidly and is present in low concentrations at the site. Volatilization with reaction in the atmosphere with hydroxyl radicals is the most important fate and transport process for trichloroethylene in water and near surface soils. Trichloroethylene readily leaches into groundwater. Its K_{ow} and K_{oc} indicate significant

TABLE 1-7   PHYSICAL AND CHEMICAL PROPERTIES OF SELECTED POLLUTANTS OF CONCERN[a]

Contaminant	Molecular Weight, g/mole	Solubility in Water, mg/L	Vapor Pressure, mm Hg	Specific Gravity, 20 C	Henry's Law Constant, atm-m³/mol	Log Octanol/Water Partition Coefficient, log K_{ow}	Carbon Partition Coefficient, K_{oc}, mL/g
Benzene	78	1,750	75	0.88	0.00559	2.13	83
Chlorobenzene	113	466	11.7	1.11	0.00372	2.84	330
Trichloroethylene	131	1,100	78	1.46	0.00910	2.38	126
Tetrachloroethylene	166	150	18	1.63	0.02590	2.60	364
Phenol	94	93,000	0.34	1.07	0.000000454	1.42	14.2
1,2-Dichlorobenzene	147	100	1.00	1.30	0.00193	3.60	1,700
bis(2-Ethylhexyl)phthalate	391	-	-	-	-	-	530,000
Polychlorinated biphenyls	328	0.031	7.70E-5		0.00107	6.04	3,900
Benzene hexachloride[b]	285	0.0060	1.09E-5	1.57	0.000681	5.23	
Arsenic[c]	151	3.02E6	0.00	2.0			

(a) Data from USEPA (1986) and Handbook of Chemistry and Physics (1973).
(b) Hexachlorobenzene
(c) Orthoarsenic Acid

adsorption and retardation in groundwater systems. Trichloroethylene has a moderate bioaccumulation potential (Frietag, et al. 1985).

Tetrachloroethylene

Tetrachloroethylene is used as a solvent, heat-transfer medium and in the manufacture of fluorocarbons (NAS 1977). Tetrachloroethylene is a purgeable organic contaminant examined and is a suspected carcinogen. It has an MCLG of 0 ppm, an ambient water quality criteria for carcinogenicity protection of human health of 8×10^{-4} ppm for the ingestion of water and organisms and is present in low concentrations at the site. Tetrachloroethylene volatilizes into the atmosphere were it reacts with hydroxyl radicals to produce HCl, CO and CO_2. Tetrachloroethylene is significantly denser than water and very insoluble. It may move as a nonaqueous phase below the water table. Tetrachloroethylene will sorb strongly to soils with high organic content and may be highly retarded in soils containing organic matter. The degree of biotransformation and degradation are unknown.

Dichlorobenzene

Dichlorobenzenes have been used as insecticidal fumigant (moth balls), space deodorant and sanitizer (in toilets and refuse containers) (NAS 1977). Dichlorobenzenes were found in numerous wells and in high concentrations. They are base/neutral extractable organic compounds, slightly soluble in water, slightly volatile and tend not to photooxidize in air. The 1,2-isomer has an MCLG of 0.62 ppm, and has an ambient water quality criteria for toxicity protection of human health of 0.4 ppm for the ingestion of water and organisms. Dichlorobenzene has a modest bioaccumulation potential (Frietag, et al. 1985). Its K_{ow} and K_{oc} indicate significant adsorption and retardation in groundwater systems.

Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate is a base/neutral extractable compound, is found in modest concentrations at the site, and has a rather high ambient water quality criteria for toxicity protection of human health of 15 ppm for the ingestion of water and organisms. Bis(2-ethylhexyl)phthalate has a modest bioaccumulation potential and does not readily photooxidize in air (Frietag, et al. 1985).

Phenol

Phenol is an acid extractable organic compound on the EPA Priority Pollutant list. It is highly soluble in water and is found in high concentrations in groundwater at the site. The low K_{ow} of phenol indicates that it would not be significantly retarded in groundwater flow. Its low K_{oc} suggests that sorption and bioaccumulation are not important fate processes. The Ambient Water Quality Criteria for toxicity protection of human health from the ingestion of water and organisms is 0.35 ppm. Biodegradation can be a significant fate process in aquatic systems and soils where microorganisms are abundant. Photooxidation and metal-catalyzed oxidation are important

degradative processes. There is a possibility that phenol in surface waters can volatilize, but rapid oxidation in the troposphere makes any significant atmospheric transport unlikely.

Polychlorinated Biphenyls

Polychlorinated biphenyls (Aroclor on the EPA Priority Pollutant list) are used in the production of capicitors and transformers. They are highly persistent and can accumulate in the environment. Concentrations of polychlorinated biphenyls in monitoring wells at the site are low. The low vapor pressure, low solubility and high K_{ow} and K_{oc} indicate that they are very strongly associated with the particulate phase and tend not to volatilize or be transported with the groundwater. They do not readily photooxidize in air. They are suspected carcinogens and have an MCLG of 0 ppm and an MCL of 0.35 ppm. The Ambient Water Quality Criteria for carcinogenicity protection of human health by the ingestion of water and organisms is only 7.9×10^{-8} ppm. Polychlorinated biphenyls have a strong tendency to bioaccumulate.

Benzene Hexachloride

Benzene hexachloride (hexachlorobenzene) is the common name use to designate the mixed isomers of 1,2,3,4,5,6-hexachlorocyclohexane. The most common commercial use is in the production of the insecticide Lindane. It is a base/neutral extractable organic compound and is a suspected carcinogen. It has an Ambient Water Quality Criteria for carcinogenicity protection of human health by ingestion of water and organisms of 7.2×10^{-7} ppm. It has a relatively low water solubility and vapor pressure; it does not readily photooxidize in air, and it is strongly associated with the particulate phase. Lindane has a relatively low persistence in the environment. It has a very large tendency to bioaccumulate. Benzene hexachloride was found in low concentrations at the site.

Arsenic

Arsenic is a naturally occurring metal. It can be introduced to the environment by means of feed additives and pesticides. It has an MCLG and MCL of 0.05 ppm and an Ambient Water Quality Criteria for carcinogenicity protection of human health by ingestion of water and organisms of 2.2×10^{-6} ppm. It is modestly soluble in water, but its other physical and chemical properties depend on the form of the arsenic (oxidation state). It was found in modest concentrations throughout the study area.

2.0 HYDROGEOLOGY

Bergstrom and Walker (1956) described the geology of the American Bottoms and related the geology of the water-yielding deposits to groundwater reserves. The topography is that of a nearly level flood plain which has a slight slope to the south. Alluvial deposits in the Bottoms average 115 feet thick, have a maximum thickness of 180 feet (Searcy et al. 1952) and have filled a broad, deeply cut bedrock valley. In the study area, these deposits range from 140 feet thick near the river at the Monsanto and SSDRA sites to about 70 feet in the eastern part of the investigated area. Large supplies of groundwater are withdrawn primarily from valley fill deposits comprised of permeable sand and gravel (Wehrmann 1979). Groundwater in the American Bottoms is mostly found in a semiconfined condition, but it may also occur in a water table condition (Voelker 1984). Semiconfined conditions are present where fine-grained deposits overlie coarser, more permeable deposits. Water table conditions are present where fine-grained deposits are absent, and the upper surface of the zone of saturation is in coarse deposits (Schicht 1965).

The core descriptions in the Appendices of the Geraghty & Miller (1986a, 1986b) and Ecology and Environment (1988) reports support these earlier interpretations. The geologic cross section (Figure 2-7), illustrates that the alluvial deposits fine upward from the bedrock, and contain a few tens of feet of coarse sand and gravel which is overlain by about 50 feet of sand. Fine sands, silt, clay lenses and fill deposits overlie the sand unit. Schicht (1965) and Bergstrom and Walker (1956) conclude that the combined effect of variations in grain size (coarsening with depth) and degrees of sorting within the valley fill have caused the hydraulic conductivity of the valley fill to increase with depth. These variations in conductivity affect the groundwater flow system and ultimately the transport of contaminants within the study area.

To facility the hydrogeological evaluation of the area, the valley fill sequence has been divided into three zones--water table, intermediate and deep--based on relative hydraulic conductivities. These zones have been assigned based on the lithology described in boring logs, in the literature and in aquifer test results compiled by Schicht (1965). Geraghty & Miller (1986a,b) adopted this classification scheme for the vertical distribution of the unconsolidated deposits. Ecology and Environment (1988) also adopted this hydrogeologic classification scheme for interpreting the field data, but elected to use a more simplified (water table aquifer underlain by a confined, intermediate aquifer) description for their computer simulations.

Although there are vertical differences in the geologic materials and aquifer properties, the studies cited above have demonstrated that the aquifer is semiconfined. In fact, the water table elevation and potentiometric surface data presented in Figures 2-1 through 2-6 illustrate that water from the deeper unconsolidated deposits is at most under only 4 feet of confining pressure, and in most cases differs from the water table elevation by less than a foot. Ecology and Environment (1988) report that the aquifers not only are all hydraulically connected, but that their intermediate and deep aquifers were not under artesian pressure during the period of study. In
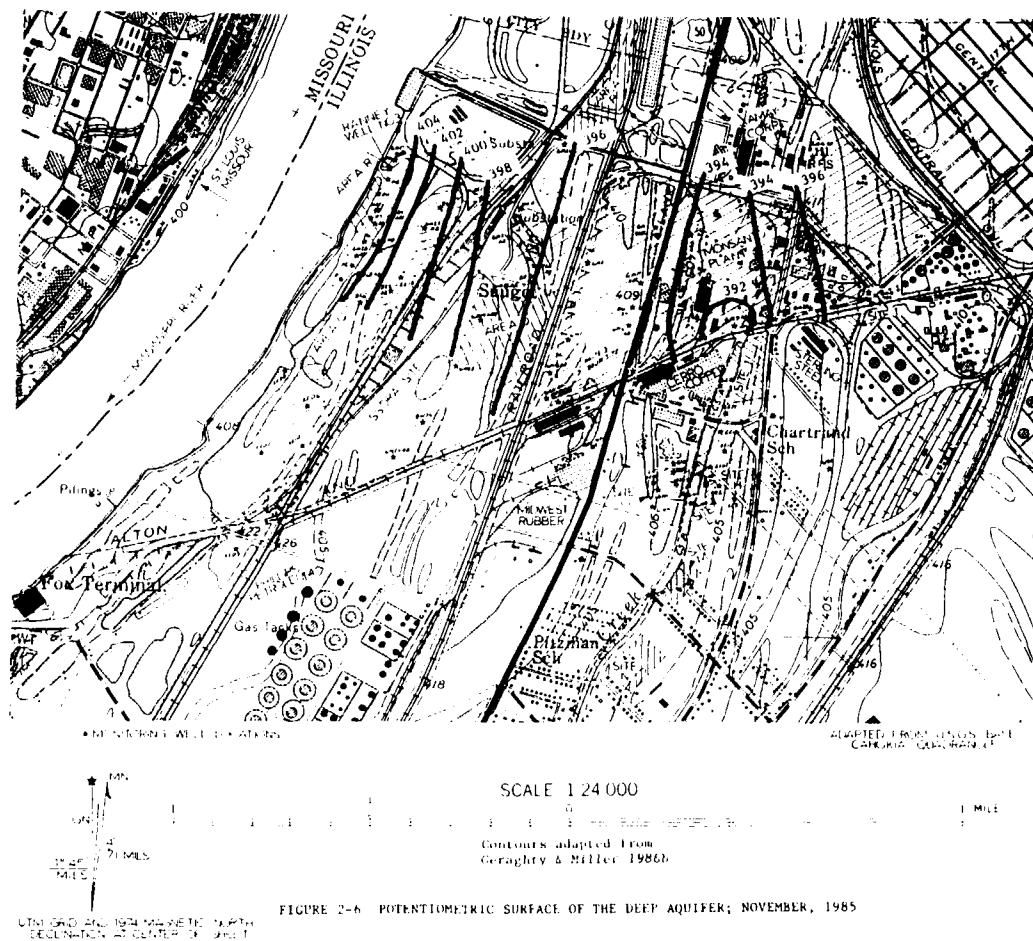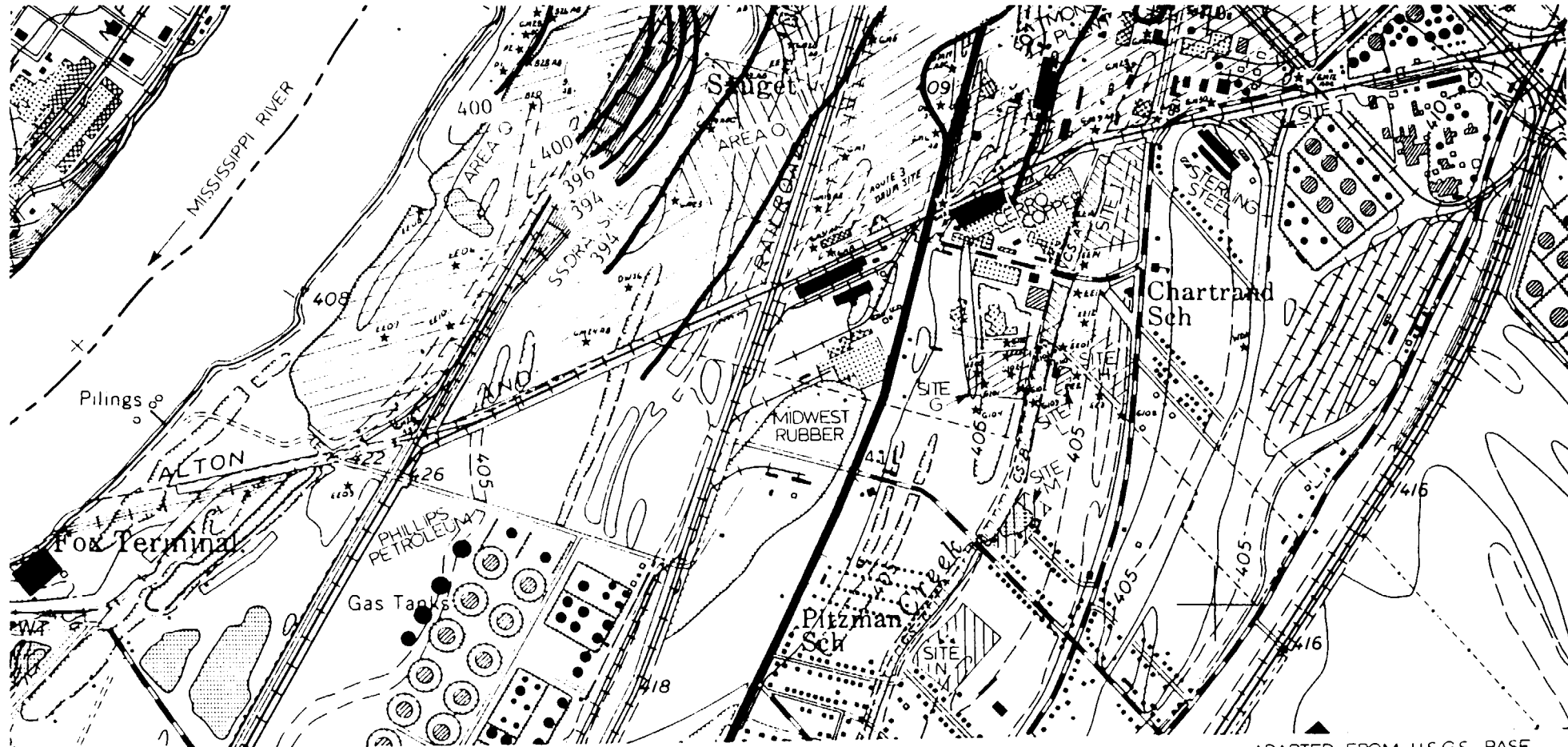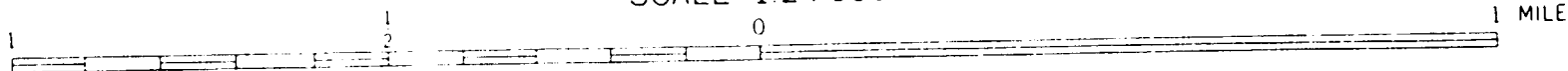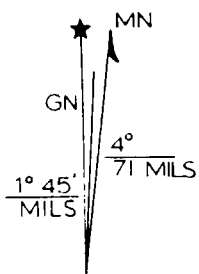
SCALE 1:24 000

Contours adapted from
Geraghty & Miller 1986b

FIGURE 2-6 POTENTIOMETRIC SURFACE OF THE DEEP AQUIFER; NOVEMBER, 1985

★ MONITORING WELL LOCATIONS

ADAPTED FROM U.S.G.S. BASE
CAHOKIA QUADRANGLE

SCALE 1:24 000

1 MILE

Contours adapted from
Geraghty & Miller 1986b

MN

GN

4°
71 MILS

1° 45'
MILS

UTM GRID AND 1974 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

FIGURE 2-1   CONFIGURATION OF THE WATER TABLE; AUGUST, 1984

ADAPTED FROM U.S.G.S. BASE
CAHOKIA QUADRANGLE

SCALE 1 24 000

1 MILE

Contours adapted from
Geraghty & Miller 1986b

UTM GRID AND 1974 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

FIGURE 2-1 CONFIGURATION OF THE WATER TABLE; AUGUST, 1984

SCALE 1 24 000

1 MILE

Contours adapted from
Geraghty & Miller 1986b

FIGURE 2-2 CONFIGURATION OF THE WATER TABLE; NOVEMBER, 1985
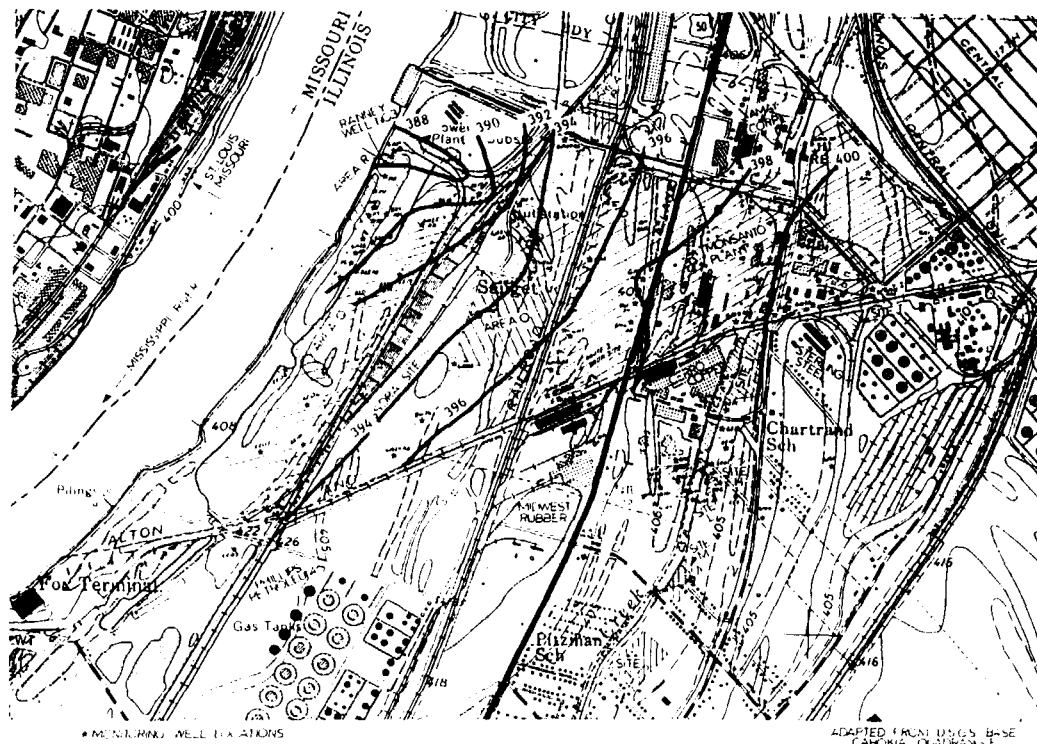
SCALE 1 24 000

Contours adapted from
Geraghty & Miller 1986b

FIGURE 2-3 POTENTIOMETRIC SURFACE OF THE INTERMEDIATE
AQUIFER; AUGUST, 1984

2-4
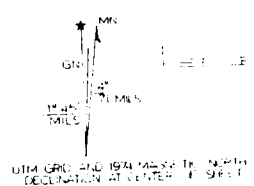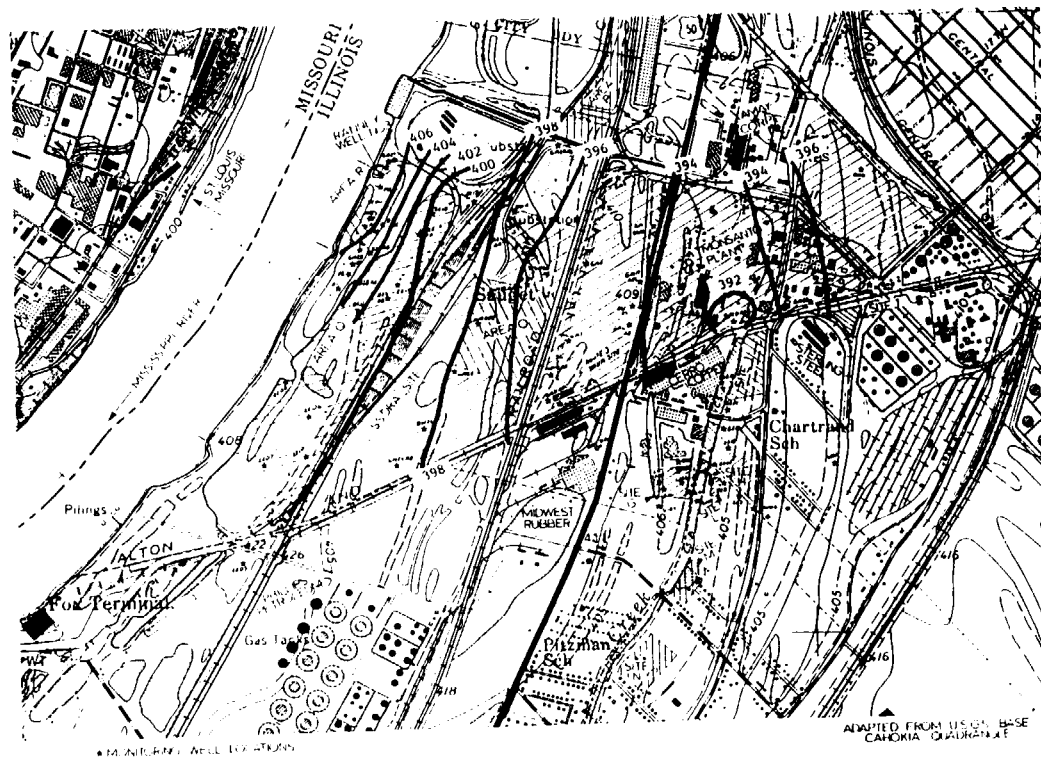
SCALE 1:24 000

Contours adapted from
Geraghty & Miller 1986b

FIGURE 2-4   POTENTIOMETRIC SURFACE OF THE INTERMEDIATE
AQUIFER; NOVEMBER, 1985
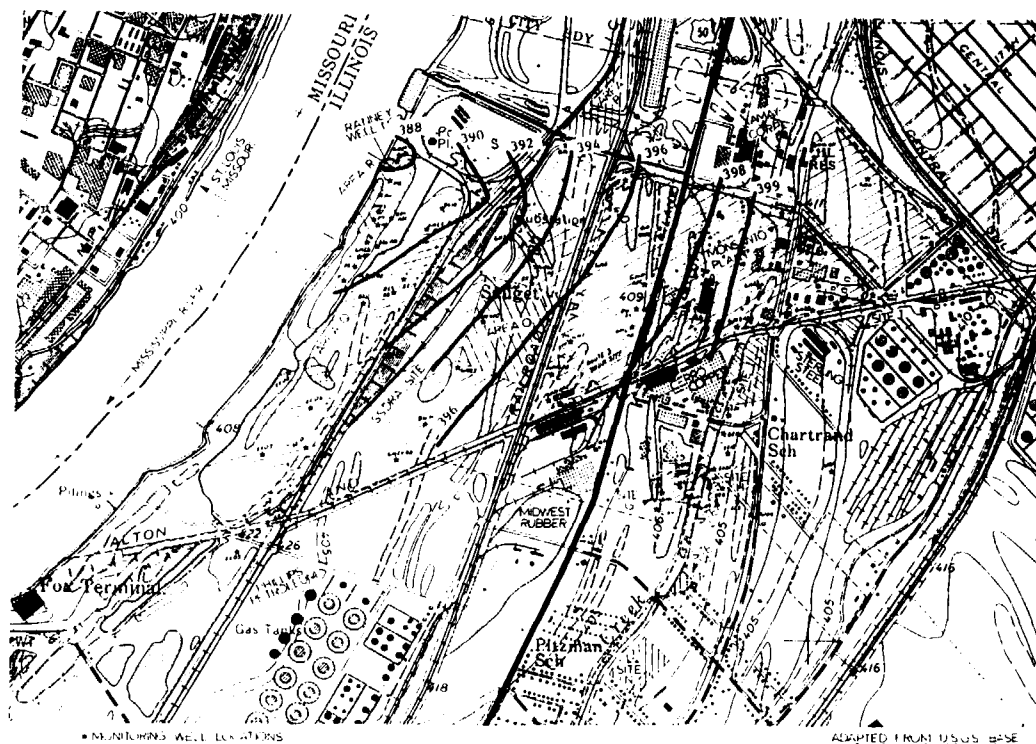
2-5

SCALE 1 24 000

Contours adapted from
Geraghty & Miller 1986b

FIGURE 2-5 POTENTIOMETRIC SURFACE OF THE DEEP AQUIFER; AUGUST, 1984

WEST   **EAST**

Elevation[a]

┌── Mississippi River

400 ft ──   ▽ Water Table   Ave. Elev. 396 ft   Cahokia
                                                              Alluvium
                 Groundwater Velocity = 0.02 ft/day[b]   Shallow Aquifer   (Recent)
                                                          Clay and Silty Sand

350 ft ──   Groundwater Velocity = 4.4 ft/day   Intermediate Aquifer Sand   Henry
                                                                                        Formation
                                                                                        (Wisconsin)

300 ft ──   Groundwater Velocity = 6.4 ft/day   Deep Aquifer
                                                          Glacial Till

                 Limestone Bedrock   Bedrock
                                                                             (Mississippian)

(a) Above mean sea level
(b) Velocities from Geraghty & Miller 1986 a, b

FIGURE 2-7   GENERALIZED HYDROGEOLOGIC CROSS SECTION (SAUGET, ILLINOIS)

other words, the entire fill sequence is a single aquifer. They cite the differences in permeability and the resulting effects on contamination migration as the major reason for maintaining a distinction among the units. Nevertheless, both studies elected to describe the hydrogeology in terms of the four distinct aquifers shown in Figure 2-7 (shallow, intermediate, deep and bedrock). That formalism will be retained in this presentation.

2.1   Aquifer Characteristics

2.1.1   Water Table Aquifer

2.1.1.1   Geologic Parameters

The Cahokia Alluvium consists of unconsolidated, poorly sorted materials with several sand and clay lenses. The material averages about 40 feet thick and becomes coarser with depth. These recent alluvium and valley fill deposits unconformably overlie the Henry Formation. The contact between the two units was not recognized during the drilling program executed by Geraghty & Miller (1986a,b). At the W.G. Krummrich Landfill site, several discontinuous lenses of silty/sandy clays interbedded with silty sands ranging in thickness from 20 to 50 feet have also been identified. All shallow wells in the Geraghty & Miller (1986a,b) studies and all monitoring wells installed in the Ecology and Environment (1988) study were finished within this unit.

2.1.1.2   Hydrogeologic Parameters

The water table aquifer extends from the water table to a depth of approximately 45 feet below the ground surface. It averages 35 feet in thickness.

Several slug tests were conducted by Geraghty & Miller (1986a,b) and Ecology and Environment (1988) personnel to determine aquifer transmissivity, hydraulic conductivity and the storage coefficient. The method used by Geraghty & Miller (1986a,b) to analyze the data was developed for use in wells screened across the entire thickness of a confined aquifer. The method is not directly applicable to partial penetration of a well in a water table aquifer. Consequently, the results obtained by this method for hydrogeologic parameters in the water table aquifer are probably worthless. Similar criticisms are given in the IEPA comments (Harza Environmental Services 1987). For completeness, their results are summarized below and compared with those reported by Ecology and Environment (1988).

Slug tests also were performed by Ecology and Environment (1988) to determine the in-situ hydraulic conductivity of the water table aquifer materials. Their method of data analysis utilized the Hvorslev (1951) method, in which it is assumed that the aquifer is unconfined, the well is of small diameter and the length of the screen is small compared with the length of the well. These assumptions are more appropriate than those used by Geraghty & Miller (1986a,b). Consequently, the hydraulic conductivities reported by Ecology and Environment (1988) are more likely to approximate the true values.

The hydraulic conductivities of the water table aquifer calculated by Geraghty & Miller (1986a,b) ranged from 1.9 to 23 gallons per day per square foot (gpd/ft^2) and averaged 9.5 gpd/ft^2 (Table 2-1). The calculated transmissivity values ranged from 28.5 to 344.3 gpd/ft and averaged 141.5 gpd/ft. In the landfill area adjacent to the Mississippi River, permeabilities were reported in the range of 0.004 to 8.7 gpd/ft^2 based on laboratory analyses of soil borings and ranged from 3.8 to 127.2 gpd/ft^2 in field measurements. Using the average values for the hydraulic conductivity and an effective porosity of 15%, an average linear velocity may be calculated from Darcy's Law to be 0.02 feet per day. The results of the slug tests performed by Ecology and Environment (1988) yield hydraulic conductivities in sites near Cerro Copper (Figure 1-1) that range from 9.9 gpd/ft^2 to 212 gpd/ft^2 with an arithmetic average of 75.2 gpd/ft^2. Using these values for the hydraulic conductivity in Darcy's equation yields a calculated average velocity of 0.0053 ft/day (19.4 ft/year). Their study also involved determining hydraulic conductivities in sites along the river. They report values ranging from 13.8 gpd/ft^2 to 330 gpd/ft^2 with a mean value of 121.1 gpd/ft^2. Using these values the groundwater velocities can be calculated, but they are highly variable due to fluctuations in the water table gradients caused by changes in the river stage. Ecology and Environment (1988) report velocities ranging from 0.0363 ft/day to 0.3246 ft/day with an average value of 0.1702 ft/day when the gradient is towards the river.

It is necessary to emphasize that determination of the velocity is critically important in predicting the migration of contaminant plumes. In the Geraghty & Miller (1986a,b) reports, it is based on the improperly determined hydraulic conductivities cited above. Furthermore, since most contaminants reach the groundwater system by migrating through the water table aquifer, all migration and release rates based on these values are highly suspect. The hydraulic properties of the water table aquifer is the most important uncertainty in their reports. These extremely low velocities (especially in the Geraghty & Miller (1986a,b) studies, but also in the Ecology and Environment (1988) investigation) indicate that the water table zone alone is not a significant pathway for off-site migration of contaminated groundwater into the Mississippi River. However, the hydraulic interconnection between the water table zone and the much more permeable intermediate zone provides such a pathway. The significance of the interrelationship between these two zones and the potential effect on contaminant migration is a major finding of the Ecology and Environment (1988) study.

Recharge of groundwater is received from direct infiltration of precipitation and runoff (including floodwaters), subsurface flow of infiltrated precipitation from the bluff area to the east and induced infiltration from adjacent riverbeds where pumpage has lowered the water table below the level of the river. Precipitation is probably the most important recharge source. Schicht (1965) calculated the average rate of surface recharge to be about 371,000 gallons per day/square mile (gpd/mi^2) for the Sauget/Cahokia area.

Depending upon the stage of the Mississippi River and the local recharge rate, groundwater flow can be either into the American Bottoms from the Mississippi River or toward the river from the alluvial deposits. This is illustrated in Figures 2-1 and 2-2 which display the water table and inferred groundwater flow direction during August, 1984 and November, 1985. The configuration of the water table in August 1984 (Figure 2-1) indicates that groundwater flow is

TABLE 2-1   HYDROGEOLOGIC PARAMETERS OF AQUIFERS

Aquifer	Hydraulic Conductivity (K), gpd/ft²	Transmissivity (T), gpd/ft	Storage Coefficient (S), Dimensionless	Velocity (v), ft/day	Method	Source
Water Table	9.5	141.5[a]	_[b]	0.02[c]	Slug Test	(d)
Water Table	75.2-121.1	-	-	0.005-0.17	Slug Test	(e)
Landfill	26.5	-	-	-	-	(f)
Intermediate	1,620[a]	120,200	0.1033	-	Pump Test	(g)
Intermediate	3,300[a]	165,000	0.040	4.4[c]	Pump Test	(d)
Deep	2,600[a]	211,000	0.061	6.4[c]	Pump Test	(f)

(a) Calculated from T=Kb, where b is the aquifer thickness.
(b) - = No value derived.
(c) Calculated from v=KI/xn, where I is the hydraulic gradient, x=7.48 g/ft^3, n = effective porosity.
(d) Geraghty & Miller (1986a) and Geraghty & Miller (1986b).
(e) Ecology and Environment (1988).
(f) D'Appolonia Waste Management Services as reported in (c).
(g) Schicht (1965) as reported in (c).

toward the Mississippi River. The highest water levels (404' MSL) are found beneath the Monsanto property, and the water table elevation decreases toward the Mississippi River. The lowest water table elevation (388' MSL) is located just north of the Krummrich landfill, and it reflects the pumping of several dewatering wells in the intermediate zone (see Figure 2-3). There is also a groundwater mound beneath the Krummrich landfill. The high water level beneath the plant and the landfill probably accelerate the discharge of contaminants from these sites to the groundwater. In contrast to the low river stage in August 1984, the Mississippi River was about 15 feet higher in November 1985 (U.S. Army Corps of Engineers 1988). The configuration of the water table in November 1985 (Figure 2-2) shows that the high river stage has caused a reversal in the groundwater flow direction with water moving into the alluvial sediments from the Mississippi River. To the east, groundwater flow is still toward the river, except directly under the Monsanto plant where the water is mounded. The degree of fluctuations in water levels within any given monitoring well due to changes in river stage decreases with distance away from the river. For example, during the Ecology and Environment (1988) study, the average change in water levels at Site Q was 5.05 feet, compared to 3.38 feet at Site O and 1.52 feet at Site G. These sites are progressively farther from the river.

2.1.1.3 Present and Historic Use

Historically, groundwater was not obtained from water table wells, but rather it was drawn from the deeper sand and gravel aquifer in the Henry Formation. There are presently at least 16 dewatering wells in the area. Depending on their design, they may remove water from the water table aquifer.

2.1.2 Middle Aquifer

2.1.2.1 Geologic Parameters

The middle aquifer is generally situated in the Mackinaw Member of the Henry Formation. This unit lies unconformably on top of the bedrock and beneath the surficial unconsolidated deposits of the Cahokia Alluvium. It consists of Wisconsinan glacial outwash in the form of valley-train deposits. It is highly variable in thickness (70 to 100 feet) and is about 95 feet thick at the Mississippi River. It becomes thinner with increasing distance from the river. These unconsolidated deposits are medium to coarse grained sand and gravel. Grain size increases with depth. Geraghty & Miller (1986a,b) divide this unit into two aquifers based on the transmissivity data they collected. They define the middle aquifer as an intermediate permeability zone between 40 and 90 feet below the surface. Ecology and Environment (1988) classifies the intermediate aquifer as the medium- to coarse-grained sand and gravel extending from 45 to 75 feet below the surface. A depth of 75 feet was chosen for the bottom of the aquifer based on boring logs presented by Schicht (1965).

2.1.2.2   Hydrogeologic Parameters

Geraghty & Miller (1986a,b) summarize the aquifer test data reported in Schicht (1965) and determine mean transmissivity and permeability values to be 120,200 gpd/ft and 1,620 gpd/ft^2, respectively (Table 2-1). The storage coefficients are representative of water-table conditions, as they range from 0.020 to 0.155. An additional pump test was conducted at the Monsanto property in 1983. The results are somewhat suspect because the pump rate varied during the early portion of the test, but Geraghty & Miller (1986a,b) evaluated the data and report a transmissivity of 165,000 gpd/ft, hydraulic conductivity of 3,300 gpd/ft^2 and storage coefficient equal to 0.04. These results are in good agreement with those reported by Schicht (1965) and suggest that the intermediate aquifer is well represented by these data. Using the hydraulic conductivity calculated from the transmissivity of the intermediate zone, an aquifer thickness of 50 feet and an effective porosity of 20%, an average linear velocity is calculated from Darcy's Law to be 4.4 feet per day. Ecology and Environment (1988) did not install monitoring wells in this interval, nor did they conduct any pumping tests on existing wells.

Like the water table aquifer, groundwater flow can be either into the middle aquifer from the Mississippi River or toward the river from the alluvial deposits. This is illustrated in Figures 2-3 and 2-4 which display the potentiometric surface and inferred flow directions during August, 1984 and November, 1985. The configuration of the potentiometric surface in August 1984 (Figure 2-3) indicates that groundwater flow is toward the Mississippi River. The highest water level (400' MSL) is found beneath the Monsanto property, and the water level generally decreases toward the Mississippi River. The lowest elevation (388' MSL) is located just north of the Krummrich landfill and probably reflect the pumping of several dewatering wells. In contrast to the low river stage in August, 1984, the Mississippi River was about 15 feet higher in November, 1985 (U.S. Army Corps of Engineers 1988), and it affected the configuration of the potentiometric surface. Figure 2-4 shows that the high river stage has caused a reversal in the groundwater flow direction with water moving into the alluvial sediments from the Mississippi River and toward the cone of depression caused by dewatering activities directly under the Monsanto plant.

2.1.2.3   Present and Historic Use

In the past, large supplies of groundwater were withdrawn from the permeable Henry Formation. Most wells were not screened in the middle aquifer, but in the coarsest deposits overlying bedrock (here referred to as the deep aquifer). However, some wells are screened in this interval. Several dewatering wells also are screened in this aquifer and the effects of that pumping on the potentiometric surface are described above.

2.1.3   Deep Aquifer

2.1.3.1   Geologic Parameters

Geraghty & Miller (1986a,b) define the deep aquifer as the most permeable material encountered in the area. Like the middle aquifer, the deep aquifer is geologically classified as part of the Henry Formation. It lies between about 90 feet and bedrock (approximately 130 feet). In some areas, till and/or boulder zones lie 10 to 15 feet above the bedrock. Ecology and Environment (1988) classify the deep zone as the coarsest deposits of the Henry Formation which directly overlie the bedrock. They determine the zone to be from 75 feet to 130 feet below the surface.

2.1.3.2   Hydrogeologic Parameters

Schicht (1965) reported aquifer pump test data from wells deep enough to be in the deep aquifer. Mean transmissivity and permeability values were calculated to be 211,000 gpd/ft and 2,600 gpd/ft^2, respectively (Table 2-1). The coefficient of storage represents water table conditions at the Monsanto site (0.082) and at another location two miles to the east (0.100). These results are similar to those reported for the intermediate aquifer, and they suggest that the entire alluvial interval may be more appropriately described as a single, unconfined aquifer rather than as the three distinct aquifers purported by Geraghty & Miller (1986a,b). Using the hydraulic conductivity calculated from the transmissivity of the deep zone, an aquifer thickness of 50 feet and an effective porosity of 20%, an average linear velocity is calculated from Darcy's Law to be 6.4 feet per day. Ecology and Environment (1988) did not install any monitoring wells in this interval, nor did they conduct any pumping tests on existing wells.

Like the water table and intermediate aquifers, groundwater flow can be either into the deep aquifer from the Mississippi River or toward the river from the alluvial deposits. This is illustrated in Figures 2-5 and 2-6 which display the potentiometric surface and inferred flow direction during August, 1984 and November, 1985. The configuration of the potentiometric surface in August 1984 (Figure 2-5) indicates that groundwater flow is toward the Mississippi River, similar to that observed in the intermediate zone. The highest water level (399' MSL) is found beneath the Monsanto property and the water levels generally decrease toward the Mississippi River. The lowest elevation (388' MSL) is located just north of the Krummrich landfill. This probably reflects the pumping of several dewatering wells. In November, 1985 the potentiometric surface of the deep zone was similar to that of the intermediate aquifer. Figure 2-6 shows that the high river stage has caused a reversal in the groundwater flow direction with water moving into the alluvial sediments from the Mississippi River and towards the cone of depression caused by dewatering activities under the Monsanto plant.

2.1.3.3   Present and Historic Use

By far, most of the past groundwater supplies were derived from wells screened in the deep, permeable sand and gravel deposits of the Henry Formation. Groundwater pumpage in this area over the last 100 years was largely from industrial wells. Pumpage was estimated (Richey et al. 1984) to have increased from significantly less than 1 million gallons of water per day in 1890 to a high of about 35.5 million gallons per day in 1962. As a result of a regional deterioration of water quality, groundwater withdrawals decreased from their high in 1962 to 0.5 million gallons per day in 1980.

In 1961 heavy pumping of the supply wells on the Monsanto property caused a large, regional cone of depression to develop (Richey et al. 1984). The drawdown at the center of the cone of depression was about 40 feet. This induced flow toward the Monsanto property from adjacent properties (AMAX, Cerro and Mid-West Rubber) and possibly from the Mississippi River. In June, 1973, groundwater levels were at record high elevations. Decreased pumpage at the Monsanto property resulted in drawdown at the cone of depression to about 10 feet. This elevation difference was sufficient to induce localized flow from all directions toward the Monsanto property. By November, 1980, the cone of depression at the Monsanto property was less than 5 feet deep, and the flow pattern returned to natural discharge into the Mississippi River.

The lowering of the water table as a result of past groundwater withdrawals in the area had changed the natural groundwater flow direction from west to radial flow toward pumpage locations at the Monsanto plant and the Monsanto Ranney Well No. 3. A significant cone of depression, great enough to draw groundwater from as far away as Cerro Copper, formed in the early 1940s and existed until sometime between 1977 and 1980. During this period, groundwater withdrawals caused groundwater levels to be below the surface of the river and resulted in induced infiltration. Schicht (1965) estimated the induced infiltration recharge volume to be approximately 18.5 mgd, or approximately 58% of the 31.9 mgd being withdrawn.

2.1.4   Bedrock Aquifer

The surficial unconsolidated deposits unconformably overlie Mississippian limestone. In some places, the bedrock aquifer consists of dolomite and lesser amounts of sandstone and shale. Further east, the alluvial deposits are underlain by Pennsylvanian bedrock. Almost all of the wells in the area produce from the unconsolidated deposits; furthermore, most of the larger industrial wells produce from the coarser, more permeable sands and gravels of the deep aquifer. A few static water level measurements near the Mississippi River in November, 1985 indicate that the bedrock aquifer behaves similarly to that of the deep aquifer. Otherwise, the Geraghty & Miller (1986a,b) and Ecology and Environment (1988) reports give no more information about the geology, hydrology, past use or chemical contamination of the bedrock aquifer.

2-15

3.0   GROUNDWATER SAMPLING AND MONITORING

3.1   Summary of Sampling and Monitoring Programs

The data presented in the background reports were collected in October, 1983
at the Monsanto site and in July, 1984 at the SSDRA site by Geraghty &
Miller (1986a,b) and in March, 1987 by Ecology and Environment (1988)
(Figure 1-1). Geraghty & Miller's field programs involved the installation
and sampling of 12 wells, but they expanded their study to include soil boring
investigations, additional monitoring well installation, aquifer
characteristics determination, water level and water quality data collection
and selected soil sample analyses. Ecology and Environment's (1988) field
activities included geophysical investigations, soil gas monitoring, surface
water and sediment sampling, surface and subsurface soil sampling,
hydraulic conductivity testing, infiltration testing, groundwater sampling and
air sampling. The geophysical surveys were conducted in October and December,
1985. The remaining field investigations were conducted during the period
October, 1986 to October, 1987.

3.1.1   State/Federal Agency Programs

There are wells in the area that have been monitored for other projects. The
IEPA has established several monitoring wells, and the U.S. Army Corps of
Engineers has several observation wells in the general area. Details of those
monitoring programs and data were not available for inclusion with this
report.

3.1.2   Contractor Programs

Almost all information contained in this report and the conclusions reached
are the product of the Geraghty & Miller (1986a,b) sampling and monitoring
programs at the Monsanto and SSDRA sites and the Ecology and Environment
(1988) Dead Creek Project report.

The areal extent of the Geraghty & Miller (1986a,b) sampling programs is
limited. The reports contain little data beyond the property boundaries of
those two sites. Furthermore, some wells were sampled only once while others
were sampled several times. Water quality samples were collected in eight
sampling periods from November, 1983 to February 1986 at the Monsanto site.
Only the last six sampling rounds included the SSDRA site. Although most
USEPA priority pollutants were analyzed for in each sample, there are some
samples in which the entire spectrum of analyses were not performed. The
drilling and installation of wells for the Ecology and Environment (1988)
study was performed from December, 1986 to March, 1987. Slug tests were
conducted in May, 1987, and water level data were collected in March, May and
October, 1987. A single round of groundwater samples was collected from all
monitoring wells, four residential wells and one active industrial well in
March, 1987. Because of sample breakage, a few wells were resampled in July,
1987.

Included with the contractor reports are the recommendations for additional groundwater monitoring. Geraghty and Miller (1986a,b) proposed that seven wells from just three locations be monitored on a semi-annual basis for volatile organic compounds at the SSDRA site. Other pollutants would be tested for in samples collected from one or two wells. For the Monsanto site, they proposed a similar plan: 18 wells from six locations in the plant area and 11 wells from five locations in the landfill area would be monitored on a semi-annual basis for volatile organic compounds. Other pollutants would be analyzed in samples collected only from selected wells. In both cases, they recommended that the semi-annual sampling should cease in 1989 after five years of monitoring. This would total 11 data points for trend analysis. No other wells from beyond the property boundaries of these two sites were included in the monitoring plans. It is not known if this proposed plan has been implemented or if any additional data has been collected since February, 1986. Ecology and Environment (1988) did not make specific recommendations for additional groundwater monitoring.

3.2   Distribution and Concentrations of Pollutants

3.2.1   Present Distribution and Concentration of Pollutants

The areal distribution of selected contaminants are presented in Figures 3-1 through 3-9. Three pollutants were selected for representation on these maps: benzene, 1,2-dichlorobenzene and phenol. They were chosen because of their widespread distribution, high concentrations and differing physical and chemical properties (see Table 1-7). Other contaminants, such as chlorobenzene, are present in significantly higher concentrations but were not selected because of their similarity to one of the other compounds.

The concentration and distribution of each of these three pollutants is shown for each of the three aquifers in Figures 3-1 through 3-9. Because of the limited data available, only two contours are used: greater than zero and greater than 1,000 ppb. In general, the contours are similar in all three aquifers and for all three pollutants. There is a narrow (2,500 feet north to south) plume that extends from the eastern edge of the Monsanto property across the landfill (Site R) to the Mississippi River. The plume is present in all three aquifers, but the concentrations decrease with depth. This suggests that it is incorrect to treat the system as a water table aquifer overlying two confined aquifers, because the lower two aquifers are hydraulically connected to the surface and receive the same contaminates from the sources. The lower concentrations probably reflect sorption and retardation of the pollutants as they migrate downward. Some contamination also is found south of the east-west trending plume. High, localized concentrations of contaminants are found along Dead Creek at Sites G, H and I. Along the Mississippi River at Site Q, low contaminant concentrations are found in water table wells. There are no data in this area from deeper wells.

Both the Geraghty & Miller (1986a,b) and Ecology and Environment (1988) reports claim that the contaminant plumes increase in areal size with downward migration. Although this seems reasonable, the data presented in Figures 3-1 through 3-9 and in the Appendices of all three reports do not support this conclusion.
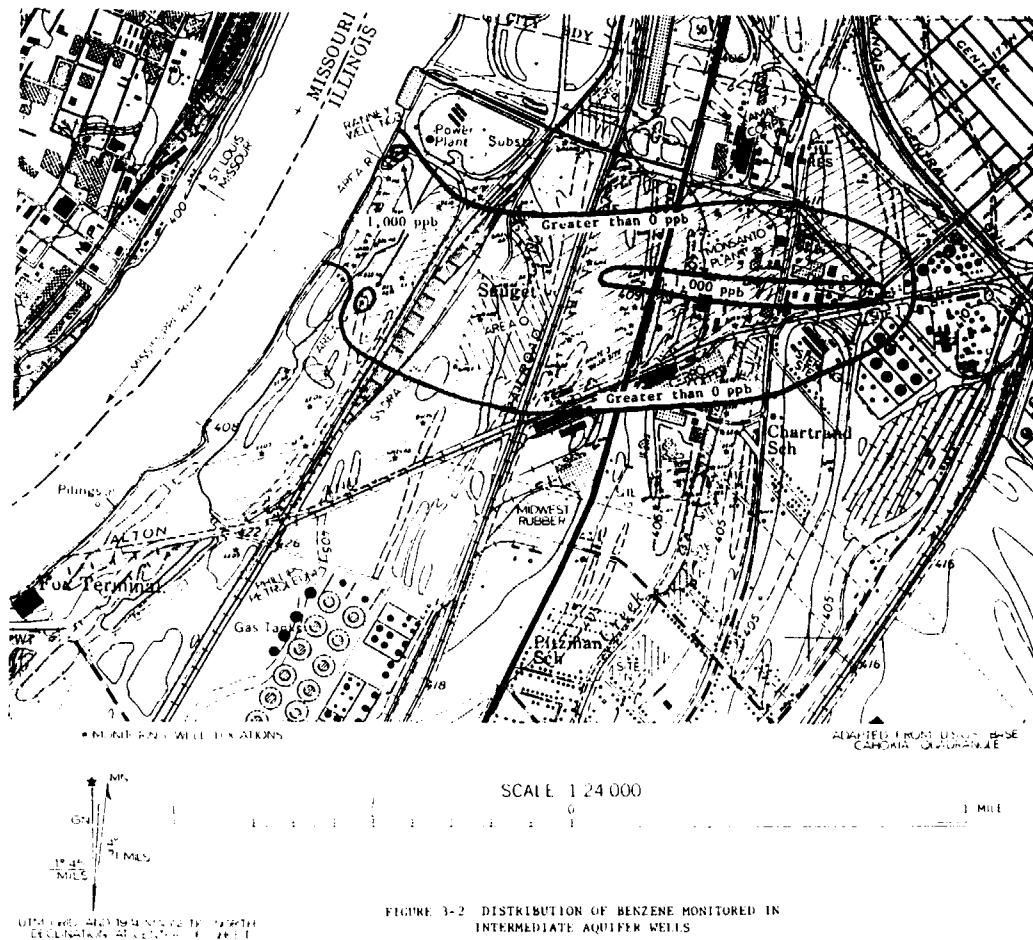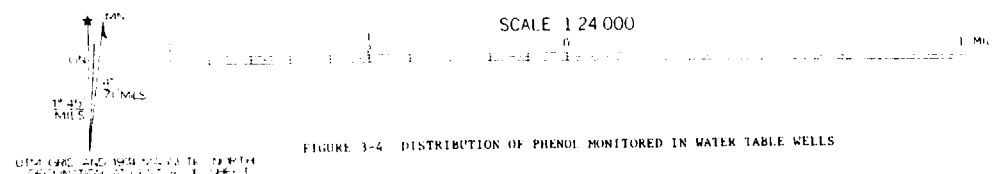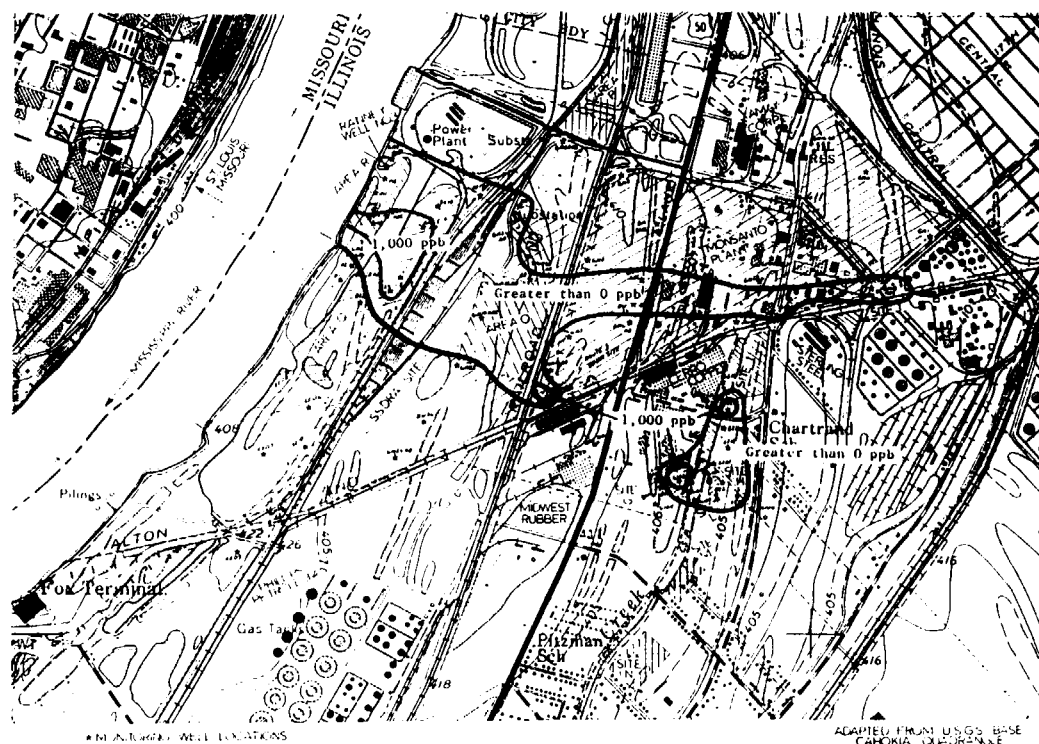
3-2

SCALE 1 24 000

FIGURE 3-1 DISTRIBUTION OF BENZENE MONITORED IN WATER TABLE WELLS

FIGURE 3-2 DISTRIBUTION OF BENZENE MONITORED IN
INTERMEDIATE AQUIFER WELLS

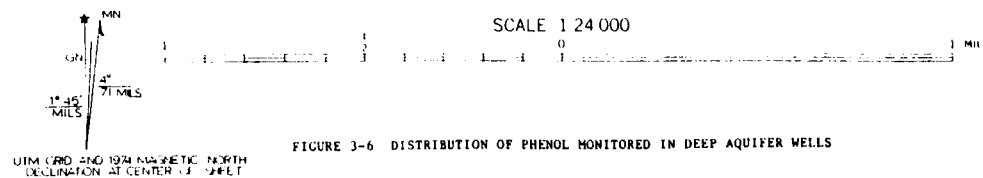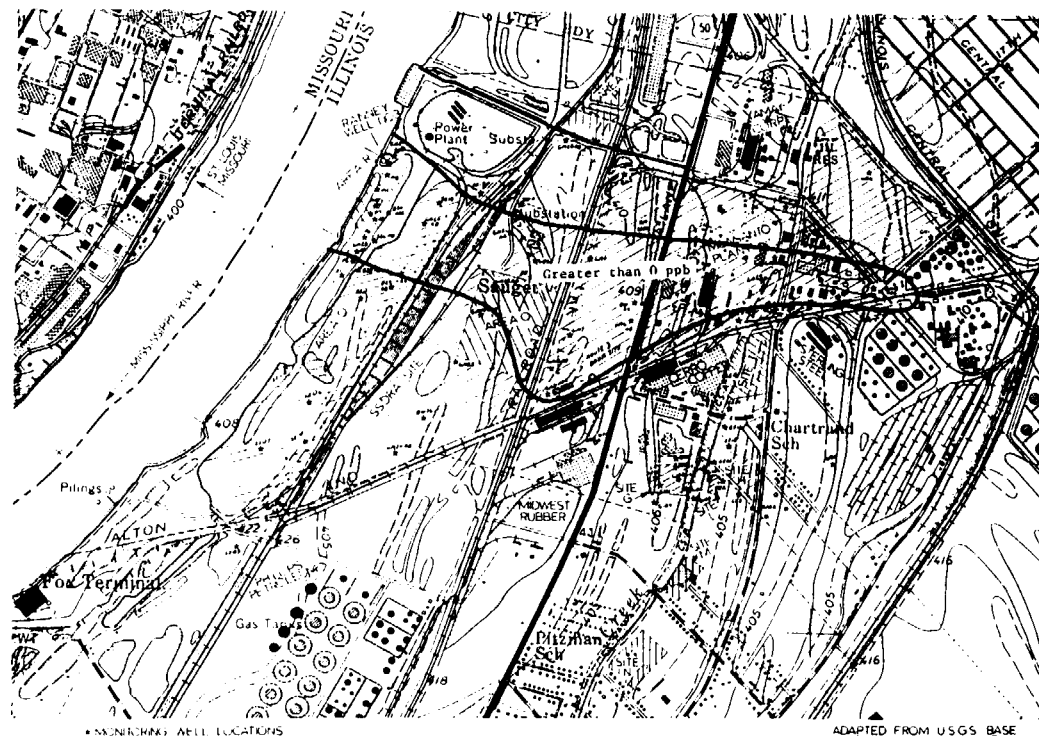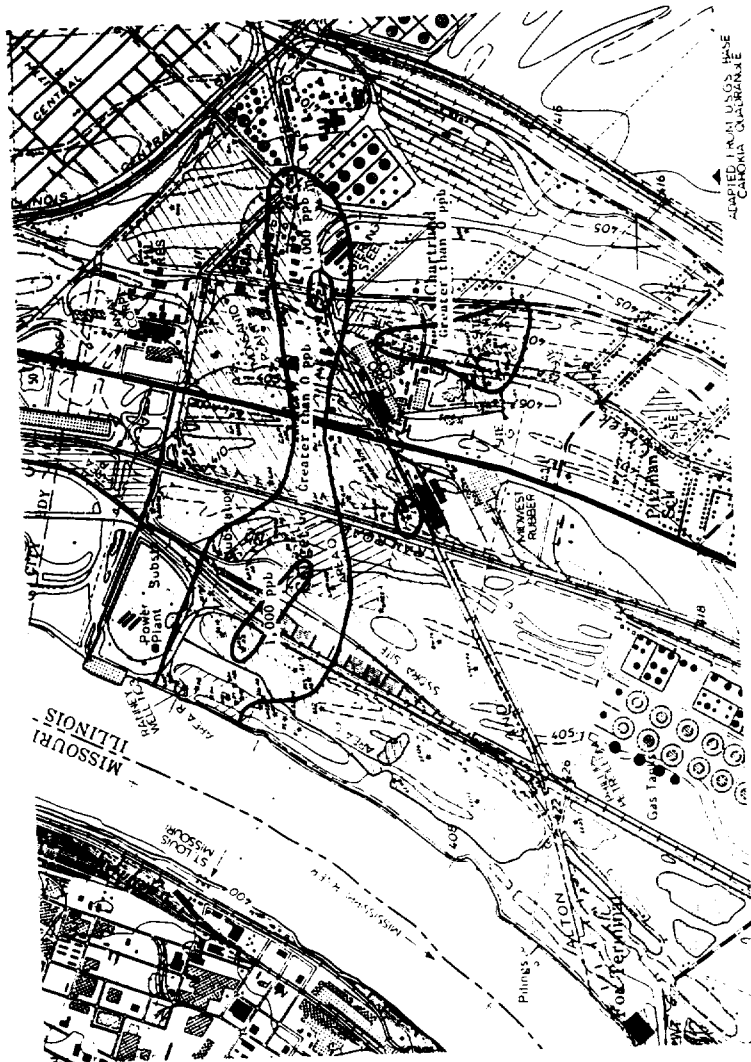SCALE 1 24 000

SCALE 1 24 000

FIGURE 3-3 DISTRIBUTION OF BENZENE MONITORED IN DEEP AQUIFER WELLS

SCALE 1 24 000

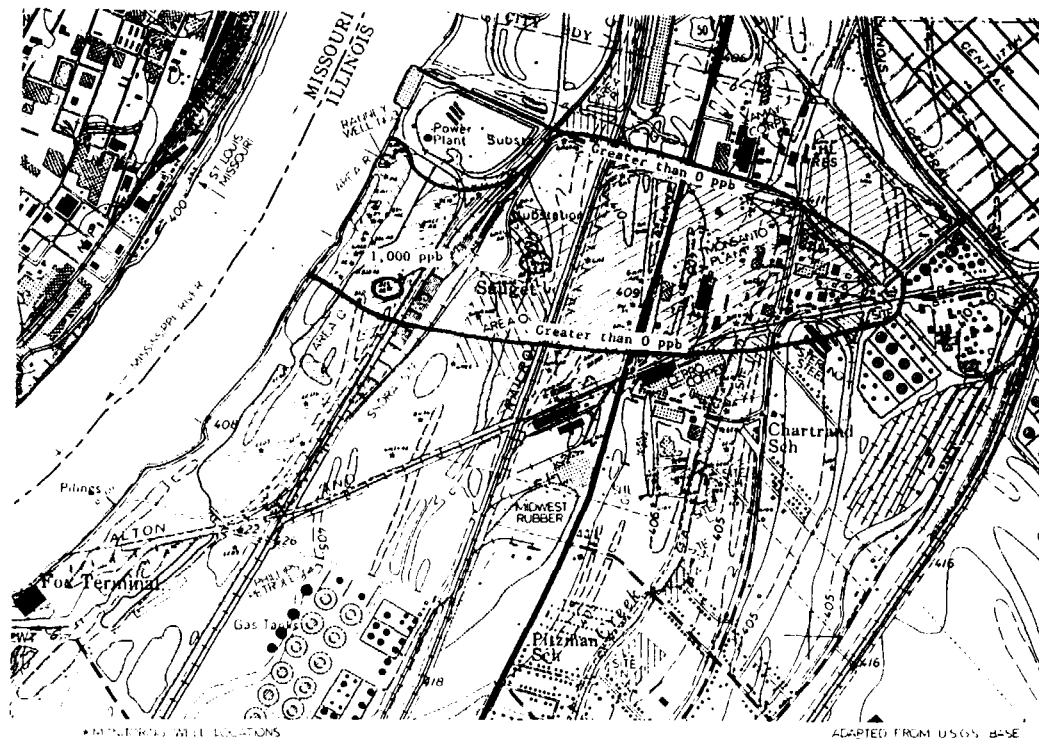0   1 MILE

FIGURE 3-4   DISTRIBUTION OF PHENOL MONITORED IN WATER TABLE WELLS

ADAPTED FROM USGS BASE
CAHOKIA QUADRANGLE

SCALE 1 24 000

1 MILE
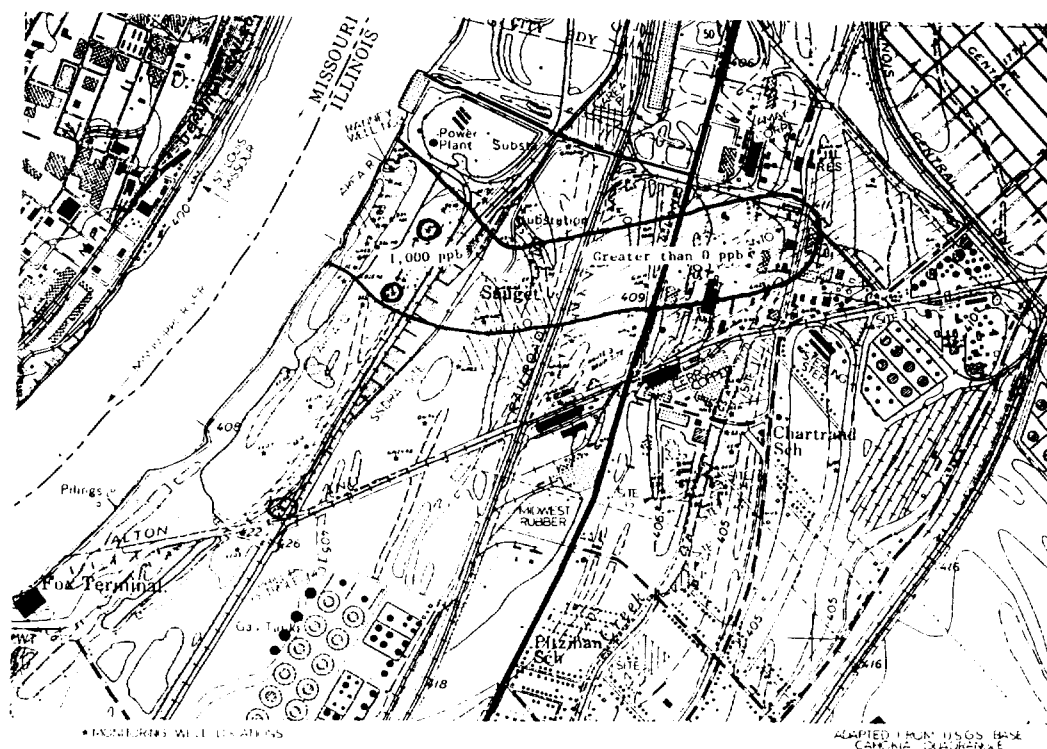
FIGURE 3-5 DISTRIBUTION OF PHENOL MONITORED IN
INTERMEDIATE AQUIFER WELLS

FIGURE 3-6 DISTRIBUTION OF PHENOL MONITORED IN DEEP AQUIFER WELLS

SCALE 1 24 000

* MONITORING WELL LOCATIONS

ADAPTED FROM U.S.G.S. BASE
CAHOKIA QUADRANGLE

UTM GRID AND 1974 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 Mile
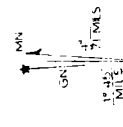
FIGURE 3-7 DISTRIBUTION OF 1,2-DICHLOROBENZENE MONITORED
IN WATER TABLE WELLS

SCALE 1:24 000

FIGURE 3-8 DISTRIBUTION OF 1,2-DICHLOROBENZENE MONITORED IN
INTERMEDIATE AQUIFER WELLS

FIGURE 3-9 DISTRIBUTION OF 1,2-DICHLOROBENZENE MONITORED
IN DEEP AQUIFER WELLS

SCALE 1 24 000

1 MILE

* MONITORING WELL LOCATIONS

ADAPTED FROM U.S.G.S. BASE
CAHOKIA QUADRANGLE

Benzene

The benzene distribution is displayed in Figure 3-1 (water table aquifer),
Figure 3-2 (intermediate aquifer) and Figure 3-3 (deep aquifer). The highest
mean concentrations are found in the shallow aquifer in wells DW-34
(199,163 ppb) and GM-17A (46,900 ppb). Those wells are located in a central
portion of the plume where all wells have mean benzene concentrations over
1,000 ppb. The plume geometry in the middle zone is essentially the same as
that in the water table aquifer. Localized contamination at Sites G, H and I
also is apparent. The highest concentration, 47,533 ppb, is found in well
GM-17B. The areal extent of contamination greater than 1,000 ppb is not as
large as in the water table zone.

The benzene concentration distribution in the deep aquifer is about the same
size as in the overlying aquifers. The highest mean concentration, 2,457 ppb,
is situated again at well GM-17C in the central portion of the plume. Note
that there is less data available from the middle and deep zones, and that
some highly contaminated shallow wells (GM-12, GM-31, EEG-107) do not have
data from deeper wells at these locations.

Phenol

The phenol concentration distribution is displayed in Figure 3-4 (water table
aquifer), Figure 3-5 (intermediate aquifer) and Figure 3-6 (deep aquifer).
Unlike the benzene distribution, there is no continuous zone of phenol
contamination over 1,000 ppb present in an east to west band through the
plume. The highest mean concentrations are found in the shallow aquifer in
wells B-29A (714,000 ppb) and B-25A (499,950 ppb) located in the landfill
adjacent to the river. Other, isolated high concentrations exist at well
GM-31A near the Route 3 Drum site and along Dead Creek at Sites G, H and I.

The plume geometry in the middle zone is essentially the same as that in the
water table aquifer, although shifted slightly to the north. The highest
concentrations occur in different locations. The highest concentration,
367,362 ppb, is found in well B-29B with the next highest concentration,
36,050 ppb, at well B-25B. Both wells are located in the landfill area.
Similarly, the areal distribution of phenol contamination in the deep zone is
about the same size as in the water table aquifer. The highest mean
concentration, 52.7 ppb at well GM-27C, is found in the landfill area.

1,2-Dichlorobenzene

The 1,2-dichlorobenzene concentration distribution is displayed in Figure 3-7
(water table aquifer), Figure 3-8 (intermediate aquifer) and Figure 3-9 (deep
aquifer). Unlike the benzene distribution, there is no continuous zone of
high concentrations in the central portion of the plume. The highest mean
concentrations are found in the shallow aquifer in wells GM-13 (2,666 ppb)
located in the eastern Monsanto plant area and GM-25A (1,895 ppb) located in
the landfill area. There are also possible isolated sources area at the Route
3 Drum site (GM-31) and along Dead Creek at Sites G, H and I.

The plume geometry in the middle zone is essentially the same as that in the water table aquifer, although the highest concentrations occur in different locations. The highest concentrations, 3,696 ppb in well B-29B and 607 ppb in well B-28B, are found in the landfill area. The distribution of 1,2-dichlorobenzene in the deep zone is similar in size and shape to the overlying aquifers. The highest mean concentration, 1,654 ppb at well GM-28C, is found in the landfill area, but well GM-12C on the eastern margin of the Monsanto property also has a high mean value (325 ppb).

3.2.2   Migration of Pollutants

The importance of past groundwater withdrawals and subsequent flow diversions lies in the effect they may have had on contaminant migration from study area sites. Beginning in the early 1940s, heavy pumping from the intermediate and deep zones of the valley fill deposits at the Monsanto facility produced a deep cone of depression which lowered the water table near the plant from the shallow zone into the intermediate zone. This caused water levels in the shallow zone at surrounding areas to drop to elevations of 370 to 380 feet above MSL. During this early period of pumpage, the excavations as Sites G, H and I were being dug. These pits were excavated to a depth of 373 to 385 feet above MSL. This depth suggests that digging progressed until the water table was encountered. These pits were subsequently filled with liquid and solid wastes. Because the bottoms of these pits were unlined and were at or near the water table, surface pumpage in the area would have drawn leachate and contaminants from the shallow zone off-site toward the pumping location and into the more permeable intermediate and deep zones. Having migrated to these deeper zones, contaminants could migrate farther and faster than possible in the relatively impermeable shallow zone. Contaminants at the eastern sites (near Cerro Copper) would not only have been drawn off-site toward the Monsanto Plant, but may also have been pulled toward the Mississippi River by the cone of depression created by the Ranney well No. 3 near Site R. The overall results of these induced flow diversions are an increase in the vertical and areal extent of contamination and the mixing of contaminants across hydrogeologic zones.

Similar contaminant migration patterns are likely to have occurred in areas adjacent to the river. However, wastes were not disposed of at Sites 0, Q and R until the late 1950s and mid-1960s. At that time, contaminants would have been drawn off-site exclusively toward the Ranney well at Site R. Flow would have continued in this direction until 1972 or 1973 when pumpage from the Ranney well was discontinued. Flow may have then been reversed toward a small cone of depression present near the Monsanto plant.

These pumping effects on contaminant migration continued until approximately 1980. At that time, significant groundwater withdrawal was discontinued and flow to the Mississippi River was reestablished. During the period 1940 to 1980, contaminants were contained within the cones of depression produced in the area, hindering the discharge of contaminants to the river. However, with the return of westerly flow patterns in 1980, the potential for contaminant discharge to the river was resumes. Except for seasonal fluctuations, this flow pattern continues today.

The east-west plume shown in Figures 3-1 through 3-9 is in agreement with the interpretation that the groundwater flow is primarily from the east to west and toward the Mississippi River. The plume is confined to a reasonably narrow path across the Monsanto and SSDRA properties from well cluster GM-12 on the east to the Mississippi River on the west.

The limited data do not enable concentration contours to be drawn in a manner that illustrates original sources for the contaminants. This may be due, in part, to multiple sources for each pollutant and/or different sources for different compounds. For example, benzene contamination in the central portion of the area may be caused by a local source, from contaminates transported into that zone from the landfill or from the Monsanto property to the east. There are also several other likely source areas such as the Route 3 Drum Site, the pits at at Sites G, H and I and the landfill at Site Q. Multiple source areas coupled with periodic and historic changes in flow directions have caused dispersion and mixing of contaminant plumes.

Another method to evaluate contaminant migration is to compare contaminant concentrations with time in wells that lie along a flow path. If a contaminant is migrating, then it will pass one location at one time and pass another location, farther downgradient, some time later with a reduced concentration (Freeze and Cherry 1979). Similarly, downward migration might be identified. Unfortunately, the available data fall far short of enabling such an approach. Sufficient temporal data along a flow path and from the same depth do not exist. Instead, only some limited temporal data exist for all three unconsolidated aquifers. The well spacings do not permit migration evaluations to be made.

Figures 3-10 through 3-15 present data for benzene, phenol and 1,2-dichlorobenzene in shallow, middle and deep aquifers at well clusters GM-12 and GM-19. These two well clusters where chosen because (1) they lie within the plumes identified in Figures 3-1 and 3-9, (2) they are screened in all three aquifers and (3) there are multiple sampling round data available. Chemical data from only four to six time sampling rounds over a 30-month period exist at well cluster GM-12 and data from only three to four sampling rounds over an 18-month year period were collected from well cluster GM-19.

Figure 3-10 indicates that benzene concentrations have significantly decreased in the shallow well (GM-12A) since May, 1984. The data also suggest that the concentrations of benzene in the middle aquifer (well GM-12B) and perhaps in the deep aquifer (GM-12C) have increased, perhaps as a consequence of downward migration, although there is insufficient data to verify those conclusions. The data for phenol (Figure 3-11) is inconclusive. The data for 1,2-dichlorobenzene (Figure 3-12) illustrates similarities to that of benzene. The limited data at well cluster GM-19 does not permit trend analysis (Figures 3-13 to 3-15).

3.2.3   Predicted Near-Term Movement of Pollutants

Groundwater transport velocities and directions are not sufficiently defined areally or vertically by the Geraghty & Miller (1986a,b) and Ecology and
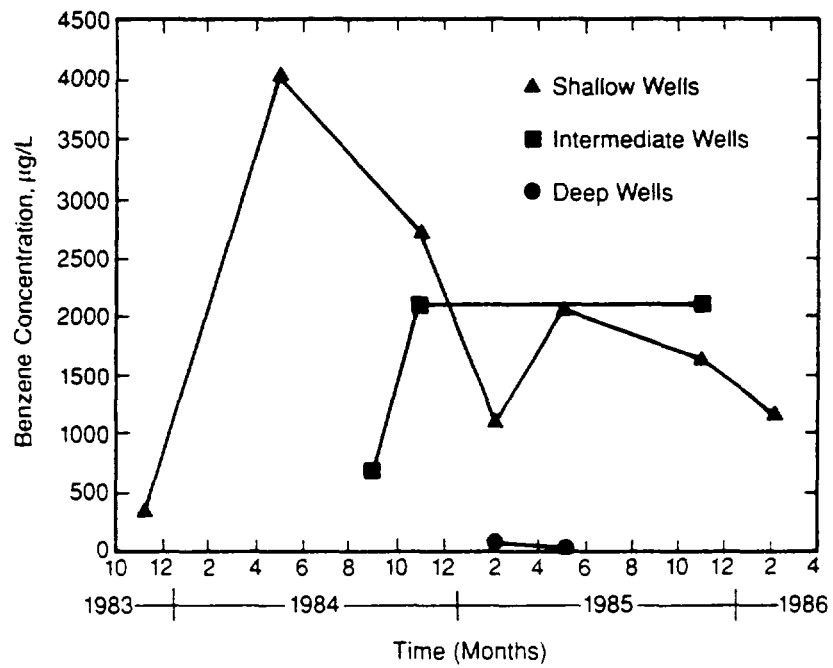
FIGURE 3-10 DETECTED CONCENTRATIONS OF BENZENE AT WELL CLUSTER GM-12
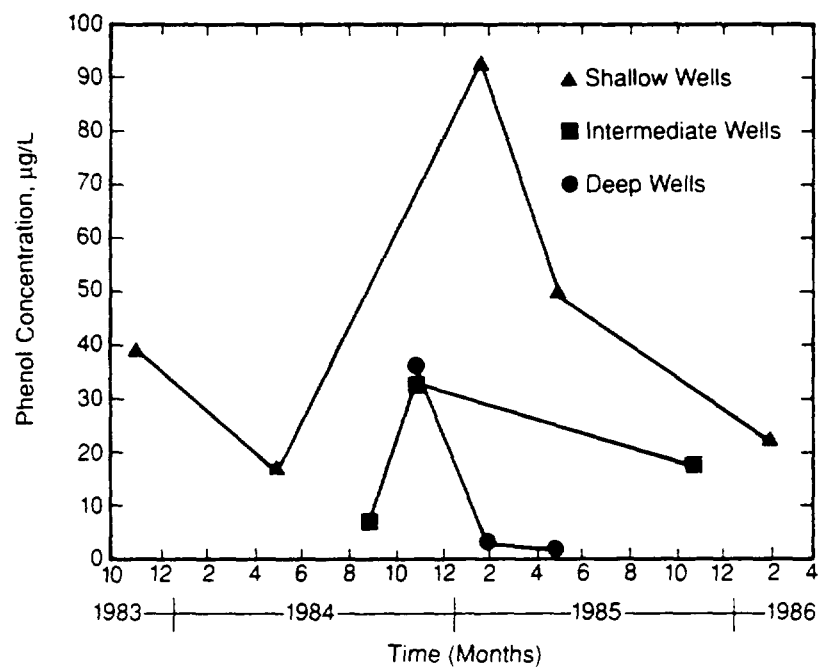
FIGURE 3-11 DETECTED CONCENTRATIONS OF PHENOL AT WILL CLUSTER GM-12
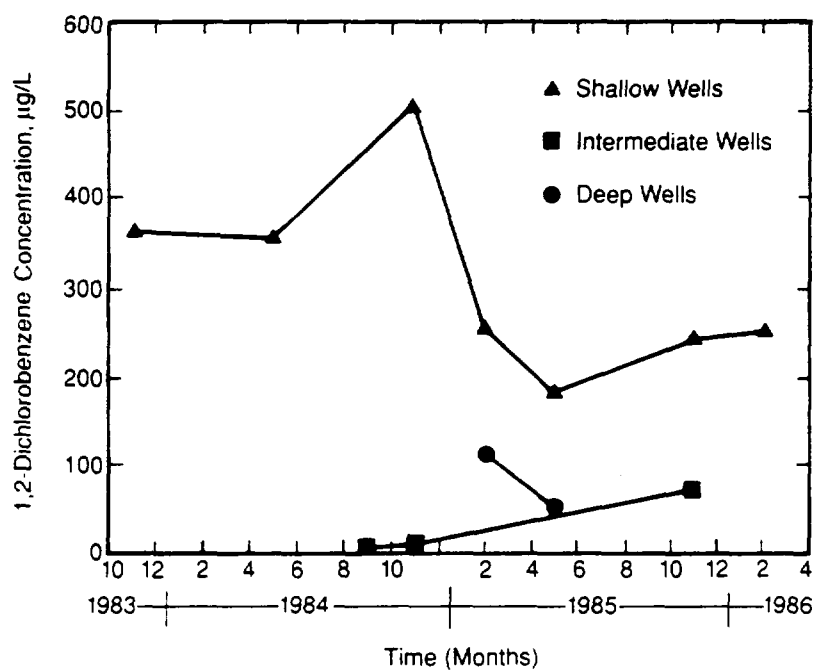
FIGURE 3-12   DETECTED CONCENTRATIONS OF 1,2-DICHLOROBENZENE
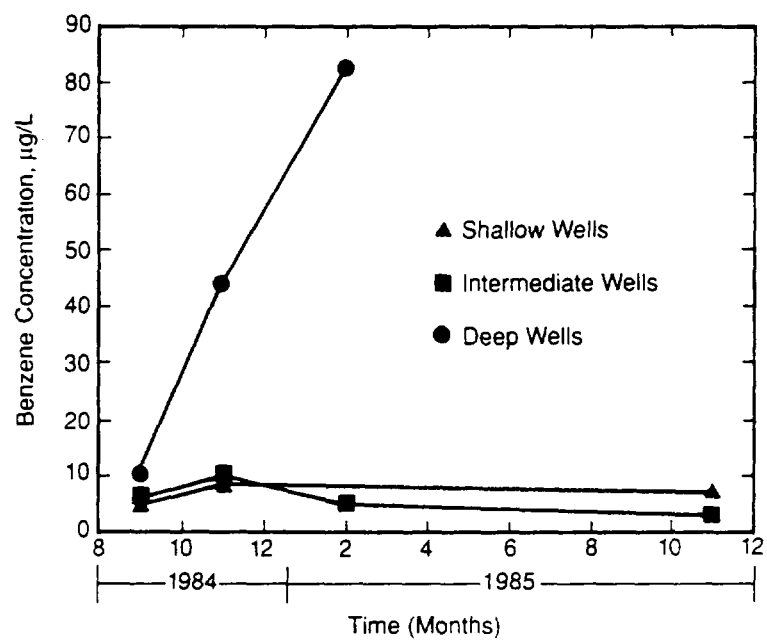AT WELL CLUSTER GM-12

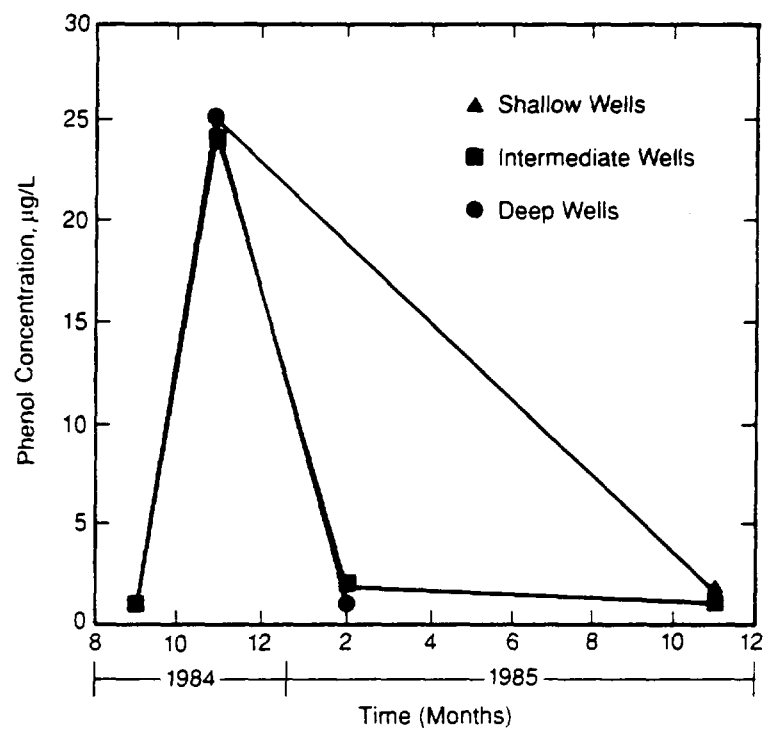FIGURE 3-13   DETECTED CONCENTRATIONS OF BENZENE AT WELL CLUSTER GM-19

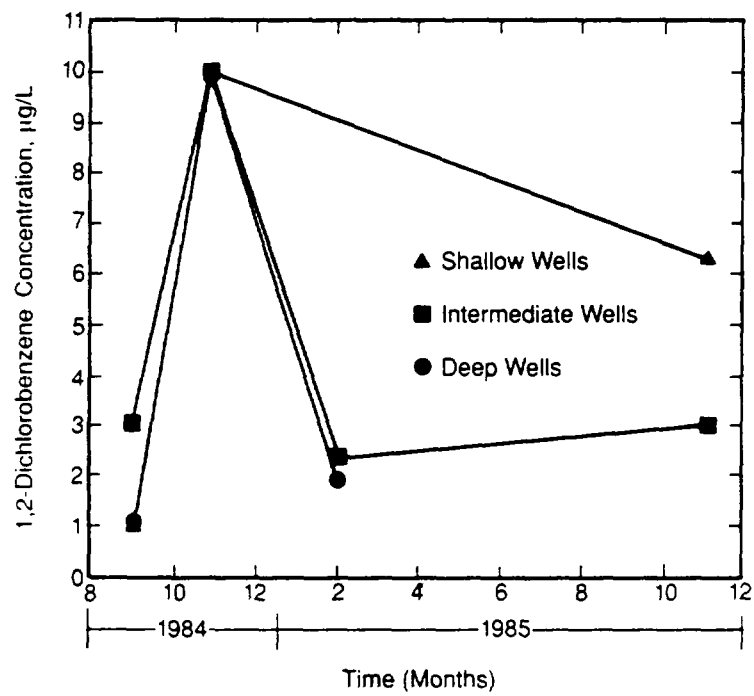FIGURE 3-14 DETECTED CONCENTRATIONS OF PHENOL AT WELL CLUSTER GM-19

FIGURE 3-15   DETECTED CONCENTRATIONS OF 1,2-DICHLOROBENZENE
AT WELL CLUSTER GM-19

Environment (1988) reports to enable accurate predictions of near-term or long-term contaminant transport. It is possible, however, to make a reasonable estimate of general contaminant migration velocities and directions. Since the contaminants are found in all three unconsolidated aquifers and in the bedrock aquifer, a transport velocity of 4 ft/day (the value calculated for the intermediate aquifer) can be used to estimate groundwater migration velocity. It should be noted that many of the contaminants have high adsorption coefficients and are therefore significantly retarded in their migration rates. Since the pumping centers are no longer a major influence on the direction of groundwater flow, contaminated groundwater will tend to move from the east toward the Mississippi River, but it will be influenced by periodic reversals of flow direction due to high river stages. With these caveats, it is reasonable to assume that the contamination will remain confined to the existing east-west plume, and they will persist if no remedial clean-up is enacted. It is likely that much of the contamination will persist indefinitely because occasional inflow from the Mississippi River reverses the flow direction and contaminants adsorbed in the soil zone will slowly be desorbed into infiltrating water. The concentration maxima will decrease slightly with time due to dispersion and dilution by recharge, but it is unlikely that the concentration will decrease to levels below the USEPA MCLs without remedial action.

Ecology and Environment (1988) used computer simulations to predict future movement of groundwater contaminants and to estimate contaminant loading to the Mississippi River. They modified the Illinois State Water Survey models (Prickett and Lonnquist 1971, Pricket et al 1981) to incorporate the effect of seasonal river stages. Major assumptions used in the modelling effort include: (1) the aquifer is homogeneous and isotropic; (2) there is a shallow water table aquifer overlying an intermediate, confined aquifer; (3) there is a uniform, vertical groundwater gradient; and (4) the retardation factor is 1.50 and longitudinal and transverse dispersivities are 50 ft and 25 ft, respectively. The groundwater flow model was calibrated by simulating groundwater heads from April, 1987 through September, 1987, adjusting parameters known to have an impact on water levels and matching simulated water levels to within one foot head difference of measured values. Their simulations show that groundwater is transmitted faster in the intermediate zone than in the water table zone. This results in a downward groundwater gradient and downward contaminant migration. The simulations show that after the contaminants migrate into deeper portions of the aquifer, they migrate horizontally toward the Mississippi River. From their model Ecology and Environment concluded that contaminants originating from Sites G, H, I and L will reach the river in approximately 20 years. Contaminants originating from Site R will reach the river in approximately eight years.

Because the general flow pattern is from higher water table elevations in the east toward the Mississippi River on the west, it is reasonable that most of the contaminated groundwater in the landfill area will discharge into the Mississippi River. Table 3-1 presents an estimate of the contaminant discharge from the landfill area into the Mississippi River. The numbers are based on the Geraghty & Miller (1986a,b) presentation on this subject, but they are modified to account for the chemicals detailed in this report. The

TABLE 3-1 ESTIMATED LOADING OF SELECTED POLLUTANTS OF CONCERN INTO THE MISSISSIPPI RIVER[a]

Contaminant	Water Table[b] Loading, lb/day	Intermediate[c] Loading, lb/day	Deep[d] Loading, lb/day	Total Loading, lb/day	Reduced[e] Loading, lb/day
Benzene	0.032	2.28	5.97	8.28	7.29
Chlorobenzene	0.201	9.80	32.95	42.95	37.80
Trichloroethylene	0.00	0.00	0.00	0.00	0.00
Tetrachloroethylene	0.00	0.00	0.00	0.00	0.00
Phenol	1.15	0.37	0.85[f]	2.37	2.09
1,2-Dichlorobenzene[g]	0.005	0.168	6.81	6.98	6.15
bis(2-Ethylhexyl)phthalate	0.0003	0.320	0.066	0.386	0.340
Polychlorinated biphenyls[h]	0.00	0.00	0.002	0.002	0.002
Benzenehexachloride[i]	0.00	0.00	0.00	0.00	0.00
Arsenic[j]	0.0015	0.30	0.0033	0.30	0.27
Totals	3.19	13.24	46.65	61.27	53.94

(a) Data from Geraghty & Miller 1986a,b.
(b) Wells P-14, P-7 and P-6 (Geraghty & Miller 1986b).
(c) Wells P-13, P-12, P-11, P-10, P-8, P-2 and P-1 (Geraghty & Miller 1986b).
(d) Wells GM27B, GM27C, GM28B and GM28C (all defined as "deep" by Geraghty & Miller 1986b).
(e) Reduced loading based on the assumption that flow is into the aquifer from the Mississippi River 12% of the time.
(f) Other phenols present in the deep zone are not included.
(g) Other dichlorobenzene isomers present are not included.
(h) Aroclor-1260. Other isomers present are not included.
(i) Hexachlorobenzene.
(j) Orthoarsenic Acid.

velocities reported in Section 2.0 of this report are used, even though the low values obtained from the water table aquifer are not considered reliable. The calculated loading to the river is reduced by 12% to account for seasonal recharge from the river. The effect of nearby dewatering wells has not been included.

Ecology and Environment (1988) also estimated contaminant loading to the Mississippi River. They used the computer model to calculate chemical transport and to report average and maximum values for total loading to the river. From the water table and intermediate zones, they estimate 47.93 lb/day and 89.3 lb/day, respectively. If the contribution from the deep zone is included, the average and maximum values for loading to the river are estimated to be 69.93 lb/day and 219.3 lb/day, respectively. These values are somewhat larger than the 77 lbs/day total pollutant loading estimated by Geraghty & Miller (1986a,b). The difference is a consequence of the higher hydraulic conductivity determined by Ecology and Environment (1988) and the inclusion of areas other than the landfill at Site R as contaminant source areas. For example, only 17% of the average annual average contaminant loading to the river is contributed from Site R. The results indicate that large quantities of these chemicals are being discharged into the Mississippi River. The contaminants that have been found in groundwater throughout the Sauget area are the same contaminants that are discharged in large quantities to the river. Benzene, chlorobenzene, phenol and dichlorobenzene (and others, not listed in the table) are discharged in large quantities. The use of a higher velocity in the water table aquifer does not significantly change the general interpretation except that phenol would be considered to be quantitatively more important at higher velocities than other pollutants.

3.3   Identification of Pollutant Source Areas

There are several known and suspected contaminant source areas in the Sauget area. The largest contaminant source area is the W. G. Krummrich Landfill (Site R) which is adjacent to the Mississippi River and contains an estimated 300,000 cubic yards of chemical waste material (Ecology and Environment 1988). The Route 3 Drum site, where about 5,000 drums containing organic chemicals were buried, is located on the western edge of the Monsanto property adjacent to the SSDRA property. Old lagoons and a pit are located near the northeast corner of the SSDRA site (Site O) where a large quantity of 'waste' was disposed. There are other potential sources of contaminants indicated by the groundwater monitoring data and the evaluation of past land-use practices. Sites G, H, I, L and Q show localized groundwater contamination and are thought to have received contaminated wastes in the past. Organic contaminants and heavy metals detected in sediments from Dead Creek indicate past discharge of process water and wastes from the Monsanto Plant, the Cerro property, the Midwest Rubber Company and the former Waggoner Trucking Company (now Metro Construction Company) had occurred. Other potential sources of contamination include past landfills and pits, leaky sewer lines, leaky underground pipelines and storage tanks and chemical spills throughout the area. These sources can be inferred from Figures 3-1 through 3-9 where local high concentrations may reflect contaminant source areas.

Previous investigations have identified common contaminants, including phenols, chlorophenols, chlorobenzenes, PAHs and PCBs at Sites G, H, I, L, O, Q, R, CS-A and CS-B. All of these compounds were listed on the waste inventories submitted by Monsanto for Site R or are manufacturing byproducts of compounds listed on the inventories.

It is possible that some contaminates enter the Sauget site from east of the Monsanto property. High contaminant concentrations are found in Well Cluster GM-12 on the eastern edge of the Monsanto property; however, no data are available east of that location to verify this possibility. These historical observations and current field data suggest that the landfill and the eastern Monsanto property have released pollutants to the groundwater. Other contaminants appears to have been released from the pit and lagoon areas of the SSDRA site and at post pits and lagoons south of the Monsanto property. Those contaminants may have been derived from releases to the sewer system by dewatering well discharge, or by accepting waste from Monsanto.

Detailed analysis by Ecology and Environment (1988) of past disposal activities using aerial photographs, chemical analyses of soil boring and computer simulations indicate that in many locations disposed contaminants are migrating downward into deeper portions of the aquifer where the horizontal velocities are much faster then the water table zone. This finding contradicts Geraghty & Miller's (1986a,b) claim that contaminants in the water table zone are reasonably immobile because of the low hydraulic conductivity of that zone. The Ecology and Environment (1988) conclusions are probably correct because (1) the measured hydraulic conductivities are not as low as Geraghty & Miller (1986a,b) report, (2) they explain the presence of large quantities of contaminants in the intermediate and deeper zones, (3) they are consistent with the spatial contaminant concentration data and (4) they are hydrogeologically self-consistent whereas the Geraghty & Miller interpretation was not.

4.0   UNCERTAINTIES

4.1   Uncertainties in Hydrogeologic Analysis

There are several major uncertainties in the hydrogeologic analysis that are a consequence of limited spatial and temporal data and of the poor design of the field studies conducted by Geraghty & Miller (1986a,b).

1. It is unclear if the groundwater system should be described in terms of more than one unconsolidated aquifer. The cluster well data indicate that in most cases the confining pressure results in a difference of less than four feet of head between the water table aquifer and the underlying intermediate and deep aquifers. In many cases no head difference can be detected. Geraghty & Miller (1986a,b) classify the system as three aquifers, but Ecology and Environment (1988) try to avoid the problem by calling it a single aquifer with different 'zones' identified by hydraulic conductivity differences. However, in their computer model, they treat the system as a water table aquifer overlying a confined, intermediate aquifer. The chemical data show that there is vertical migration of contaminants, so that the confining layers are very leaky and therefore should not be considered truly confining layers.

2. The aquifer properties of the middle and the deep aquifers are not significantly different to warrant the distinction made by Geraghty & Miller (1986a,b). Ecology and Environment (1988) does not make this distinction. The slug test in the water table aquifer performed by Geraghty & Miller was not interpreted correctly for this location. The proper method for obtaining data is a pump test. Consequently, the data are worthless. Although Ecology and Environment (1988) also performed slug tests, they used automated data recording and interpreted the data properly.

3. In the absence of a reasonable spatial and temporal data base of static water levels and chemical analyses, it does not seem prudent to describe the groundwater system in terms of three unconsolidated aquifers.

4. The spatial data do not permit accurate determination of the local and regional flow directions and flow velocities nor do they permit conclusive source area identification.

5. The spatial resolution of the data does not include enough wells from outside the property boundaries of the Monsanto and SSDRA sites, especially to the east, north and southwest.

6. The role of groundwater flow reversal caused by the Mississippi River is not well understood, particularly in terms of how it affects the leaching and migration of contaminants from the landfill area, and how it may retard the net loss of the contaminants from the groundwater system (Harza Environmental Services 1987). The

computer modelling effort by Ecology and Environment (1988) does
account for higher river stage, but long-term desorption and release
are still unknown.

7. The temporal resolution of the sampled wells include only one well
    that was sampled six times over a 30-month period. Most wells were
    sampled only twice during that time. A short-term study with such
    limited spatial and temporal data does not enable an accurate
    prediction of the source or fate of the pollutants.

8. The role of the dewatering wells is not known, nor is the historical
    pumping data for all the wells available.

9. Some of the limitations of the Geraghty & Miller (1986a,b) studies
    are best illustrated by their maps of contaminant plumes which stop
    at property boundaries. The Ecology and Environment (1988) and this
    report rectify the presentation of that data as much as possible,
    but the data are so severely constrained in space and time that it
    is difficult to reach many concrete hydrogeologic conclusions.

4.2   Uncertainties in Monitoring Analysis

The major uncertainties in the monitoring programs are a direct consequence of
the limited spatial and temporal data.

1. The high levels of detection of some of the temporal data make it
    unusable.

2. Two or three sampling rounds at most locations and only one in some
    areas do not permit the performance of accurate trend analyses. It
    is unknown if additional monitoring was performed after completion
    of the two Geraghty & Miller (1986a,b) reports. Certainly their
    proposed monitoring program will do little to help understand the
    regional hydrogeology or identify the source areas. State and
    federal monitoring analyses may help resolve some of these issues,
    but they were not available for this report.

3. The ultimate fate of contaminated water extracted from the
    groundwater system by the dewatering wells is not known. The uses
    of the contaminated water are unknown.

4. The pathways by which the contaminants may reach animal and human
    populations are unknown. The potential risks to these populations
    from inhalation of volatiles and ingestion of and contact with
    contaminated soil and water are unknown.

4.3   Uncertainties in Source Areas Identification

The major source areas identified are most likely correct, but there may be other small sources not identified previously. The history of chemical disposal is a major uncertainty in these analyses.

1. Identification of contaminants, timing of disposal and quantity of wastes disposed of in the landfill area (Site R) is not known.

2. The reasons for the high contaminant concentrations in the eastern part of the Monsanto property are not known. They may be due to a local source or, possibly, to westward migration of a source east of the property. Continued monitoring at well cluster GM-12 cannot resolve this question.

3. Contaminants disposed of in the pit and lagoon on the SSDRA site (Site O) or at Sites G, H, I and L are not known.

4. Other potential source areas (such as at Site Q) contain unknown quantities of unknown wastes.

5.0   CONCLUSIONS

5.1   Aquifer and Groundwater Parameters

Aquifer properties from the deep and intermediate zones of the unconsolidated
deposits are well described in the Ecology and Environment (1988), Geraghty &
Miller (1986a,b) reports and in previous studies. Aquifer properties of the
bedrock aquifer are unknown, and they have not been addressed in work to date.
The aquifer properties of the water table aquifer described in the Geraghty &
Miller (1986a,b) report are erroneous. All results and conclusions which
utilize those values for hydraulic conductivity, transmissivity and velocity
in the water table aquifer are highly dubious. That work needs to be
performed correctly. Ecology and Environment (1988) reports more accurate
analyses of aquifer properties in the water table aquifer, but yield similar
values for pollutant loading to the Mississippi River.

The hydrogeology is well known on a regional scale, but details of local flow
directions, the effects from dewatering wells and the from effects from the
Mississippi River are poorly understood. Modification of the local
groundwater flow paths and contaminant transport directions caused by pumping
activities is addressed in the Ecology and Environment (1988) report.

5.2   Sampling and Monitoring Results

The spatial and temporal resolution of the monitoring wells does not permit
accurate delineation of the contaminant plumes, migration directions and
velocities. The existing monitoring data are very limited in the number and
location of wells that can be used for trend analysis. The maps and graphs
presented in this report represent the most accurate portrayal of the
monitoring data possible. State and federal programs were not available in
preparing this report, and they should be evaluated in the future.

5.3   Pollutant Source Areas

Only the disposal areas which have contributed the largest quantities of
contaminants to the groundwater could be identified with the data available.
Additional information on disposal practices, frequency of disposal, waste
quantities and waste identification coupled with a systematic sample
collection program will aid in potential source area identification.

This information will be important during planning of remedial action and
during evaluation of risk and environmental impact. Obvious source areas such
as the landfill have contributed substantial quantities of pollutants to the
groundwater. Other sources, such as the Route 3 Drum site, the pits and
lagoons at Sites G, H, I and L and the landfill at Site Q, also have
contributed substantial quantities of pollutants. A possible source area to
the east of the Monsanto property has been suggested by Geraghty & Miller
(1986a,b), but no field data were collected to justify such a determination.
In fact, the existing data suggest a large contaminant source is located in
the eastern portion of the Monsanto property. If there were a contaminant
plume that has passed well cluster GM-12, then it should be migrating to the

west, and detailed sampling could define the areal extent of the plume and its velocity. The solution to identifying a possible source area in the eastern portion of the Sauget area is to establish monitoring wells in that area.

5.4   Soundness of Conclusions in Reviewed Reports

The Geraghty & Miller (1986a,b) and Ecology and Environment (1988) reports were the only original data sources evaluated in this Report. In general, those reports are of limited scope, covered a short time period and a limited field area. However, they do provide the raw data and draw some limited conclusions. Throughout this report, those data and conclusions have been critically examined. Inconsistencies and mistakes were noted where appropriate. The most significant of those are summarized here. Many additional criticisms of the Geraghty & Miller Reports are given in the IEPA comments (Harza Environmental Services 1987).

1.   The division of the unconsolidated aquifer into more than one aquifer based solely on test results may be incorrect. The aquifers are clearly hydraulically connected, and it is incorrect to treat the lower zones as a confined aquifer as was done by Geraghty & Miller (1986a,b) and in the computer modelling of Ecology and Environment (1988).

2.   The aquifer properties determined by Geraghty & Miller (1986a,b) from the slug test results were determined incorrectly, making the results and conclusions drawn from hydraulic conductivity, transmissivity and groundwater velocity in the water table zone incorrect. This includes the claim that contaminants have not moved more than 300 feet downgradient from the Route 3 Drum site. Many of the IEPA criticisms (Harza Environmental Services 1987) are based on the conclusion that the groundwater velocities calculated in the Geraghty & Miller (1986a,b) reports for the water table aquifer are incorrect. The results of the Ecology and Environment (1988) slug tests substantiate these criticisms and provide more reasonable values for the aquifer properties in the water table zone.

3.   No data are available to justify the Geraghty & Miller (1986a,b) claim that there is another contaminant source to the east of the Monsanto property. The high concentration of contaminants found in the eastern area of the Monsanto property are used to justify that claim, but no data east of well cluster GM-12 are available to substantiate the claim. The Ecology and Environment (1988) study also did not examine that area.

4.   Map presentations by Geraghty & Miller (1986a,b) of the contaminant plumes that stop at property boundaries are totally incorrect. Alternative maps for some contaminants have been prepared for this study to rectify that problem. The maps are somewhat limited by the lack of spatial resolution and extent of the monitoring wells. Incorporation of the Ecology and Environment (1988) data does not improve the situation since that study also was limited spatially and temporally.

5. The potential source areas identified by Geraghty & Miller (1986a,b) are limited to the obvious ones. There is insufficient data to support their claim of off-site sources to the east when shallow wells are contaminated on-site. Their conclusions are based on groundwater velocities in the water table zone which are incorrect. Although Ecology and Environment (1988) identified several potential source areas, their presentation does not permit distinguishing chemicals among the different sources. In fact, they note that there is a commonness of contaminants, and they suggest that Monsanto wastes have been disposed at all locations. This needs to be verified.

6. The conclusions reached by Geraghty & Miller (1986a,b) that no off-site migration of contaminants has occurred or will occur in the near future is unfounded. Regardless of the contaminant velocities in the water table aquifer, the velocities in the deep and intermediate aquifers are sufficiently high to enable contaminates to migrate thousands of feet. Furthermore, the pumping of dewatering wells has increased contaminant transport efficiency in some areas. The computer simulations of Ecology and Environment (1988) substantiate these criticisms.

7. Groundwater velocities are sufficiently high and enough time has elapsed for contaminates to have reached the Mississippi River. The extent of that contamination is a significant environmental release, contrary to the conclusions expressed in Geraghty & Miller (1986a,b).

8. The IEPA Report (Harza Environmental Services, 1987) suggests that the contaminant plume increases in areal size with depth. Although this makes sense since the increase in groundwater velocity with depth would cause this to occur, the limited data do not support such a conclusion (see Figures 3-1 through 3-9).

9. The proposed no action remedial alternative presented by Geraghty & Miller (1986a,b) is totally unjustified. No evaluation of potential animal and human exposure was made nor were a toxicity evaluation or an endangerment assessment performed.

6.0   RECOMMENDATIONS

6.1   Closing Data Gaps

6.1.1   Location of Additional Monitor Wells

Additional study of both the Monsanto and SSDRA sites as well as adjacent
areas is needed. Only a few of the sources of contamination have been
adequately identified. In particular, 'chemical fingerprinting' specific
sources to their plumes is needed. The areal extent of groundwater
contamination plumes has not been adequately delineated. Additional wells
outside the property margins in areas not previously studied need to be
installed and sampled to permit accurate mapping of the plumes. Vertical
resolution of the contamination is poor. Additional wells and/or sampling of
cluster wells is necessary. The possibility exists that the contamination
exists as multiple plumes or 'fingers' within the property sites. If that is
so, additional on-site wells will be helpful for planning remedial action.

6.1.2   Acquisition of Additional Information

Several important types of information need to be collected. Pump tests are
needed to determine the aquifer characteristics and flow velocities in the
water table aquifer. The existing data in the Monsanto and SSDRA site reports
(Geraghty & Miller 1986a,b) is at best unreliable, and all the conclusions
based on that data need revision. Better identification of the source areas is
necessary, especially with respect to the type of contaminants at each. The
reports are vague about the locations of potential source areas and past
contaminant releases. Determination of past disposal practices, quantities
and types of pollutants released into the environment, and how past pumping
activities have affected the vertical and lateral transport of the chemicals
needs to be addressed. The relationship between the Mississippi River and the
groundwater system needs to be examined in order to evaluate the effect of
flow reversal on contaminant dispersal and discharge, especially over long
intervals of time. Discharge into the Mississippi River needs to be measured.
Exactly which contaminants, from which aquifer or site and in what
concentrations they are discharged into the Mississippi River is not known,
but it will be an important component of a comprehensive endangerment
assessment. The fate of contaminated water from all the dewatering wells and
industrial pumpage is not specified in the reports, but it is important for
endangerment assessment and remedial planning.

6.2   Remedial Considerations

The Geraghty & Miller (1986a,b) reports reach the conclusion that "remedial
action with respect to groundwater contamination itself appears to be
unnecessary". Since neither an endangerment assessment nor an adequate
remedial investigation/feasibility study have been performed, such a
conclusion is not based on facts. Here, several remedial considerations are
summarized. Additional details are given in the IEPA report (Harza
Environmental Services 1987). The Ecology and Environment (1988) study did
not address remedial concerns.

1. The area east of Well cluster GM-12 needs to be examined. Only a
    few of the sources of contamination have been adequately identified.
    The areal and vertical extent of groundwater contamination plumes
    has not been adequately delineated. The roles of high Mississippi
    River stages and dewatering wells needs to be considered in any
    remedial plan.

2. All potential remedial measures need to be more thoroughly
    considered. In the interim, it would be wise to pump the water
    table zone and treat that water and water from dewatering wells.
    This initial remedial work could be started immediately.

3. The Geraghty and Miller (1986a,b) reports recommended remedial
    action at the lagoons and pit is the construction of slurry walls
    and a clay cap. Perhaps the lagoon and pit floor require some sort
    remedial action, too. A clay cap would require monitoring and
    maintenance indefinitely as would other components of a containment
    system.

4. Similar concerns expressed in (3) above are reached for the capping
    of the Route 3 Drum site with all contamination left in place.
    Furthermore, high water levels in the Mississippi River may induce
    contaminant leaching and migration into the groundwater underneath
    the cap.

5. The simplest and most reasonable single remedial action would be to
    treat contaminanted groundwater at the W. G. Krummrich Plant. Large
    quantities of contaminated groundwater can be captured in cones of
    depression caused by pumping. The treated water could then be used
    in the plant. A similar scenario can be envisioned for the
    dewatering wells near the landfill.

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